University of Alberta
Printing Department

THE UNIVERSITY OF ALBERTA

THE EFFECTS OF PRE-INDUCED MUSCULAR TENSION ON MOTOR PERFORMANCE

by

RONALD GEORGE MARTENIUK

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF ARTS

FACULTY OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

JULY, 1966

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "The Effects of Pre-Induced Muscular Tension on Motor Performance," submitted by Ronald George Marteniuk in partial fulfilment of the requirements for the degree of Master of Arts.

ABSTRACT

The purpose of this study was to investigate the effects of activation, as measured by pre-induced muscular tension, upon reaction time in a simple and a complex task. Movement time of the complex task was also studied. Ninety-two freshman university subjects, forty-six for each task, performed eight trials at each of five tension levels.

Results indicated that excessive tension significantly impeded reaction time of the complex task while not hindering the reaction time of the simple task. No facilitation of reaction time occurred for either task. Movement time followed a linear relationship with increasing tension.

ACKNOWLEDGEMENT

A wise philosopher once said that knowledge begins when an individual knows what he does not know. Through the wisdom, guidance and encouragement of several people I feel that I am just embarking on a career in which hard work and perserverence will someday lead me to know what I do not know.

I would like to thank my committee members, Dr. M.L. Howell, Dr. R.B. Alderman, Dr. S. Hunka and Mr. G. Glassford for their unceasing guidance and encouragement.

To Dr. W.R. Morford, who inspired me to pursue my present course of study, I would also like to offer my indebtedness.

For her unselfish devotion and self-sacrifice I am beholden to my wife, Violet. Without her assistance and understanding this piece of work would never have been completed.

I am also very grateful for the support and encouragement I have received, throughout my education, from my parents and more recently from my parents-in-law.

TABLE OF CONTENTS

CHAPTER PAGE

1. STATEMENT OF THE PROBLEM 1

Introduction 1

The Problem 5

The Subsidiary Problem 5

Theoretical Hypotheses 5

Importance Of The Study 6

Delimitation Of The Study 6

Definition Of Terms 6

II. REVIEW OF THE LITERATURE 8

Theories Concerning The Relationship Among Activation Level, Motor Performance And Muscular Tension . . . 8

Effects Of Muscle Tension On Performance

A. Reaction Time 18

B. Pursuit Rotor 21

C. Other Tasks 24

Effects Of Muscle Tension On Simple And Complex Tasks 27

III. METHODS AND PRODEDURES 29

Subjects 29

Experimental Design 29

Apparatus 30

Methods And Procedures 32

CHAPTER PAGE

Statistical Hypotheses 34

IV. RESULTS AND DISCUSSION 35

Results 35

Probability Levels 35

Comparison Of The Simple And Complex Tasks

In Reaction Time 35

Reliability 35

Mean Reaction Times 36

Analysis Of Variance 37

Range Test On The Overall Tension Levels 38

Trend Analysis Of The Overall Tension Levels 39

Trend Analysis Of The Tasks And Tension

Levels Interaction 39

Range Test On The Simple And Complex Task Means . . 39

Individual Comparisons 42

Comparison Of The Movement Time Means In The

Complex Task 45

Reliability 45

Mean Movement Times 46

Analysis Of Variance 46

Range Test On The Movement Time Means 47

Trend Analysis Of The Movement Time Means 48

Discussion 48

Reliability Of Reaction Time And Movement Time . . . 48

Variation Of Reaction Time And Movement Time

Mean Performances 50

CHAPTER PAGE

Comparison Of Tasks In Reaction Time When Tension Levels Are Averaged Together 51
Comparison Of Tension Levels In Reaction Time When Tasks Are Averaged Together 53
Interaction Of Tasks With Tension Levels 54
Comparison Of Movement Times Among The Tension Levels Of The Complex Task 60

V. SUMMARY AND CONCLUSIONS 62
Recommendations 63

BIBLIOGRAPHY 65
APPENDIX: Raw Scores 72

LIST OF TABLES

TABLE		PAGE
1.	Reliability Of Simple And Complex Tasks At All Tension Levels	35
2.	Mean Reaction Times And Standard Deviations For The Simple And Complex Tasks	36
3.	Analysis Of Variance For Reaction Times	37
4.	Duncan's New Multiple Range Test For Overall Tension Levels	38
5.	Trend Analysis Of The Overall Tension Levels	41
6.	Trend Analysis Of The Tasks And Tension Levels Interaction	41
7.	Duncan's New Multiple Range Test Applied To The Means Of The Simple Task	44
8.	Duncan's New Multiple Range Test Applied To The Means Of The Complex Task	44
9.	Differences Between Tasks At The Five Tension Levels	45
10.	Reliability Of Movement Times For The Complex Task	45
11.	Mean Movement Times And Standard Deviations For The Complex Task	46
12.	Analysis Of Variance For Movement Time	47
13.	Duncan's New Multiple Range Test Applied To The Movement Time Means	47
14.	Trend Analysis Of The Movement Time Means	48

LIST OF FIGURES

FIGURE		PAGE
1.	Reaction Time - Movement Time Apparatus	31
2.	Profile Of The Means For Reaction Times When Tasks Are Averaged Together	40
3.	Profile Of The Means For Reaction Time Showing The Interaction Of The Two Tasks With Tension Levels . .	43
4.	Profile Of The Mean Movement Times For The Complex Task . .	49
5.	Profile Showing The Variation Of Performance For The Simple And Complex Tasks	52

CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Duffy (14,15) has hypothesized that both the observation of human behavior and the analysis of current psychological concepts suggest only two basic respects in which behavior shows variation: direction and intensity. An organism may approach or withdraw from a stimulus situation, and this approach or withdrawal may take place at any one of many possible degrees of intensity. Duffy argues that while there are many objects, persons, and situations, and many aspects of all of these which may be approached or avoided, the behavior of the organism may always be described as approach or withdrawl in relation to some condition of the environment. This characteristic of behavior may be designated as the direction of behavior.

The behavior of the organism may also be described as always occurring with some particular degree of intensity. Approach or withdrawal may occur at a low degree of intensity, at a high degree of intensity, or at an intermediate degree of intensity. The intensity of response is measurable in terms of the force of overt action, or in changes in the internal processes associated with the release of energy. Duffy contends that for most purposes, a concept of intensity based on the measurement of internal processes appears to be a more useful psychological construct than one based on the force of overt response. Such a concept (i.e., the degree of energy release within the organism) may be referred to as the level of activation, the degree of arousal, or

the degree of energy mobilization and describes a condition conceived to vary on a continuum from a low point of deep sleep, to a high point of extreme effort or intense excitement.

While a complete description of behavior would require a full discussion of both the activation and the direction of behavior, only one of these aspects of behavior, activation, will be dealt with in this paper.

In recent years, the possible relationships between activation level and performance of motor tasks have been the subject of considerable theorizing. At present, very little empirical evidence is available on this problem. Not only are the precise relationships which exist between activation level and performance unknown, but also the distinction of which physiological functions provide reliable and valid indices of activation level has not yet been definitely established. Woodworth and Schlosberg (77) have suggested that muscular tension may be one such indicator, particularily tension of the neck muscles, since they send back a disproportionate share of proprioceptive impulses to the central nervous system. Schlosberg (66) has further suggested that "effort" may be thought of as representing activation, and that the tension level of certain muscles may be indicative of the amount of effort one puts into the performance of a task.

The concept of activation holds further significance for psychology by virtue of the fact that variations in the degree of activation are, on the average, accompanied by certain variations in overt response. The degree of activation appears to affect the speed, the intensity, and the coordination of responses. In general, the optimal degree of

activation appears to be a moderate one, the curve which expresses the relationship between activation and quality of performance being the form of an inverted "U".

The effect of any given degree of activation upon performance appears to vary, however, with a number of factors, including the nature of the task to be performed (63) and certain characteristics of the individual - such as, perhaps, the ability to inhibit and coordinate responses under a high degree of activation. Organismic interaction is the basic explanatory principle suggested (16) to account for the particular effects upon performance of various degrees of activation.

Eason and Branks (20) state in their review that a considerable amount of data has been obtained in recent years which indicates that tension level reflects the amount of effort exerted during the performance of a task, and more generally, level of activation or arousal (3,22,54, 69). This being the case, whether tension level will correlate positively or negatively with performance quality on a given task is dependent on the factor or factors responsible for a change in activation level. For example, if an increase in activation level is produced by factors extraneous to a task in which performance is being measured, then the resultant increase in tension may correlate negatively with performance on that task; but, if the increased activation reflects a greater degree of concentration on the task at hand, then tension level may correlate positively with performance.

An exception to the latter statement might be expected to occur only when one is already performing at his maximal skill level. In such case, no further improvement could occur, and there may actually be a decrement in performance (19).

Duffy (17) as mentioned earlier, stresses that all variations in behavior have a two-dimensional aspect, i.e., behavior varies in both direction and intensity. Thus, one cannot tell from changes in tension level alone whether performance on a given task has improved or deteriorated, since performance quality is also dependent upon the direction of one's behavioral activity at the time.

Freeman (27) has also stated that muscular tension may have a facilitative or inhibitory effect upon performance. He goes on to say that there is reason to believe that the more complex acts are definitely impeded by the presence of excessive tension in the behavior flux. This last statement is substantiated by Klein (41), who suggests in his discussion that for every task there might exist optimal tension levels above or below which performance is impaired, and that the quality of performance in skilled motor tasks is dependent upon the extent to which the performer manifests these optimal levels on any given occasion. Plotted graphically, Klein expects the relationship between tension and performance to resemble the inverted U function described by Duffy (16), Hebb (32) and Malmo (53).

In any study that is striving to obtain a relationship between tension and performance, the problem of establishing the optimal tension for a given performance is beset with methodological difficulties. Some of these perplexing problems are: (1) different amounts of tension must be induced in muscle groups which are remote enough from the performing member to offer no mechanical interference with its operation and yet near enough to produce a spread of excitation to the member; (2) the range of tension loads must be sufficiently great to permit the

occurrence of both inhibitory and facilitative effects; (3) the performance must be influenced by the tensions which are induced experimentally, and not be uncontrolled variations in other parts of the body; and (4) the performance under survey must not show major practice or fatigue effects because possibly these effects rather than experimentally induced tensions will become the major determinants of work output.

<u>The Problem</u>

The purpose of this study was to investigate the relationship between reaction time and pre-induced muscular tension. This aim was accomplished in two ways. First, the effects of a range of tensions on reaction time was studied separately for both a simple and a complex task. Second, the two tasks were compared together in terms of length of reaction times.

<u>The Subsidiary Problem</u>

As a subsidiary problem this study investigated what effects, if any, a pre-tension had on movement time. The movements made in this experiment were free from induced muscular tension so that any facilitation or deleterious effects in movement time could be directly related to the pre-tension.

<u>Theoretical Hypotheses</u>

1. Both the simple and complex tasks yield an inverted U relationship (quadratic trend) between tension levels and reaction time.

2. The optimal tension load for the reaction time of the complex task occurs at a lower level than for the simple task.

3. Movement times for the complex task also follow an inverted

U relationship.

Importance Of The Study

Very few studies have attempted to systematically vary the level of activation of an individual and at the same time observe its effects on performance. In general, this experiment should lend partial support to Duffy's two-dimensional aspect of personality, and more specifically should demonstrate the inverted U relationship between performance and muscle tension. A relative lack of systematic studies is now keeping research at a minimum in this area of human behavior. It is hoped that the information obtained from this study will contribute in some small way to the continuation of study in the area of activation and behavior.

Delimitation Of The Study

1. As was stated in the introduction it is not yet known for certain which physiological functions provide reliable and valid indices of activation level. Hence this study was limited in the sence that muscle tension will be taken as a reliable and valid indication of arousal level.

2. The limitation of the study to ninety-two subjects. Subjects were randomly chosen from approximately 1,600 first year physical education students.

Definition Of Terms

Activation Level. In this study the term activation level referred to the amount of muscular tension that was induced prior to the presentation of the stimulus. At zero pounds of tension the subject was working at his own natural level of activation.

<u>Muscular Tension</u>. Muscular tension was operationally defined as the amount of tension set on the apparatus, by the experimenter, prior to each set of trials. That is, prior to the trials at zero, five, ten, fifteen and twenty pounds.

<u>Pre-tension</u>. Pre-tension was defined as the "holding force" of a group of muscles before a stimulus was presented.

<u>Simple Task</u>. The simple task was comprised of a simple reaction time to a stimulus light. The subject upon perceiving the stimulus was required to depress a lever one-eighth of an inch thus enabling the experimenter to obtain reaction time.

<u>Complex Task</u>. The complex task was comprised of the simple reaction time plus a twelve inch movement of the hand to disconnect a ball suspended from the apparatus. The complex task, therefore, produced a reaction time plus a movement time.

CHAPTER II

REVIEW OF THE LITERATURE

This review will consist of three sections. The first section will deal with hypothetical constructs of activation, performance, and muscular tension. Next, the studies concerned with the effects of muscular tension on performance will be systematically reviewed. Last, the relationship between muscular tension and task complexity will be considered and pertinent studies will be cited.

Theories Concerning The Relationship Among Activation Level, Motor Performance And Muscular Tension

This thesis is based on Duffy's theory that there are only two basic modes of variation of behavior, direction and intensity (14). Duffy postulates that in behavior, differences between individuals must be differences in either the direction taken by the behavior, the energy level of the behavior, or both.

The directional aspect of behavior can be explained in terms of the significance a situation holds for a person. A subject approaches an object if he interprets it to be a means of reaching his goal; he ignores it if it appears to have no significance in relation to his goal; he avoids or attacks it if it appears to be an obstacle. To the extent that his interpretation of the situation is incorrect, his behavior will be erring. Adequate direction of behavior is dependent upon adequate response to the relationships in the situation.

Description of the directional aspect of personality requires also a description of the consistency with which a given orientation

or goal-direction is often referred to as coordination. Coordinated muscular movements are movements which are consistent with the goal. Other movements are inhibited, so that goal-direction is preserved.

The energy mobilization, or intensity aspect of behavior is described, by Duffy (14,15,17), in terms of the activity of those processes which supply the energy for overt response. The mobilization of energy varies in a continuum from a very low level, as in a coma or deep sleep, to a very high level, as in mania, extreme excitement, or great physical or mental effort. The individual's mobilization of energy varies: (1) with variations in the degree of fatigue produced by his activities; (2) as his condition varies from a wide-awake state, to a drowsy state; (3) as a result of the taking of stimulants or sedatives; (4) with changes in the general state of his health; (5) markedly with changes in the activity in which be is engaged; (6) with the degree of adaptation to the activity in which he is engaged; and (7) with variations in his interpretation of the demands of the situation.

The concept of activation holds further significance for psychology by virtue of the fact that variations in the degree of activation are, on the average, accompanied by certain variations in overt response (as will be seen in the next section of this review of the literature). The degree of activation appears to affect the speed, the intensity, and the coordination of responses. In general, the optimal degree of activation appears to be a moderate one, the curve which expresses the relationship between activation and quality of performance being the form of an inverted U.

As was indicated in the introduction, the effect of any given

degree of activation upon performance appears to vary with a number of factors, including the nature of the task to be performed, and certain characteristics of the individual - such as, perhaps, the ability to inhibit and coordinate responses under a high degree of activation.

Lindsley (51) turns to a neurophysiological approach of activation level and explains it in relationship to the ascending reticular activating system (ARAS). He explains that the reticular formation and its upward extensions project upon widespread areas of the cortex, and when activated it causes desynchronization or differentiation of electrocortical activity. This unspecific or diffuse influence of the ARAS upon the cortex has as its primary role the maintenance of a waking state. This is its general arousal function which causes the electrical activity of the cortex to shift from a state of sleep to one of wakefulness. Lindsley also believes that differential excitation in the reticular formation and/or the combination of interaction between thalamus and cortex may give rise to a specific alerting function in which attention may be focused on a single sense modality or upon a specific stimulus within a modality. The alerting function, Lindsley states, both general and specific, appear to play a role in perception, including the elaboration and integration of incoming messages.

On the other hand, Hebb (32) relates activation level and performance by psychologically naming the two different effects of a sensory event: the cue function, which guides behavior; and the arousal function, which is similar to Duffy's directional and activational aspects of behavior. Hebb explains the inverted U relationship between activation level and performance by considering the relation of cue function effec-

tiveness to level of arousal. Physiologically, he assumes that cortical synaptic function is facilitated by the diffuse "bombardment" of the arousal system, i.e., the reticular activating system. When this "bombardment" is at a low level, an increase will tend to maintain the concurrent cortical activity. That is, when arousal or drive is at a low level, a response that produces increased stimulation and greater arousal will tend to be repeated. This repetition is illustrated by the rising curve at the left. But when arousal is at a high level, as at the right of the curve, the greater "bombardment" may interfere with the delicate adjustments involved in cue function, perhaps by facilitating irrelevant responses. Thus, he concludes, an optimal level of arousal will exist for effective behavior.

However, Malmo (52), in his dissertation, disagrees with Hebb's viewpoint and offers an alternative explanation for the downturn in the curve. He states that an optimal level of "bombardment" appears quite conceivable, which, if exceeded, will prevent the required neural activity by making certain critical neurons refractory when it is their turn to fire in the sequence. Malmo concludes that such internal breakdown within the neural mechanism could account for decrement in the response, and the introduction of an explanation of interference produced by other competing responses would therefore be unnecessary.

Support for Hebb's theory of efficiency of cue utilization comes from Easterbrook (23), although the latter does not enter into a neurophysiological explanation. Easterbrook contends that whether a course of action is facilitated or disrupted by activation depends on its complexity and upon the range of cue utilization. Increased activation

tends to interfere with the use of incidental cues, perhaps diminishing their phenomenal value and delaying reaction to them. Meanwhile, however, it also tends to sharpen or concentrate action, and to perhaps enhance the phenomenal importance of central cues and expedite reaction to them.

Easterbrook regards the curvilinear relation between drive and proficiency as the resultant of two function: (1) one in which proficiency is a function of the number of cues in use, and (2) one in which the number of cues in use is negatively dependent upon drive level. He then assumes that the simultaneous use of task-relevant and task-irrelevant cues reduces the effectiveness of response to some extent; and that as the total number of cues in use is reduced, task-irrelevant cues are excluded before task-relevant cues. For any task, then, provided that a certain proportion of the cues in use are initially irrelevant cues (i.e., that the task demands something less than the total capacity of the organism), the reduction in range will reduce the proportion of irrelevant cues employed, and thus improve performance. When all irrelevant cues have been excluded, however (so that now the task demands the total capacity of the subject), further reduction in the number of cues employed can only affect relevant cues, and proficiency will fall. Hence, an inverted U relationship between activation and performance is obtained.

Eason and Branks (20), however, contradict Easterbrook's hypothesis of cue utilization. In the discussion of their findings they state that performance deterioration observed during very high levels of activation may be due in large part to subjects attending to stimuli irrelevant

to the task. They do not deny that this resembles Easterbrook's cue reduction theory. However, they refute the claim of reduction of cues, and in its place offer the theory that the total number of cues to which a subject is attending and responding may not be reduced. In fact, there may be an increase, but most of the cues may be irrelevant to the task on which performance is being measured.

In an aspect more closely related to the purpose of this thesis, Meyer (55), attempts to account for the effects of induced muscular tension upon learned and unlearned responses, or in effect, the interaction of simultaneous responses. In his Molar Laws of Interaction, Meyer states that there are two major factors which determine the degree of interaction in artificial induction situations: (1) interaction varies directly with the magnitude of the inducing response, and (2) interaction varies directly with the proximity of the simultaneous response. The crux of Meyer's theory lies in the assumption that interaction depends upon the convergence of simultaneous patterns of neural impulses. The Molar Laws of Interaction suggest that this event takes place in the nuclei of the motor system. Chang, Ruch, and Ward (7) suggest that each muscle of the body is represented by a field of efferent neurons which varies in density from the focus to the fringe. When a focus is activated with a threshold stimulus, none of the fringe cells for neighbouring muscles are fired. When the stimulus applied to the focus is more intense, excitation spreads, and progressively more cells in the surrounding fields go into action. Feedback excitation from proprioceptive end organs within muscles is both a contributor and distributor of excitation within the motor system. The effects of

proprioceptive feedback are not restricted to the focus for the muscle which contains the receptor. A characteristic property of afferent systems is a localized peripheral stimulation which gives rise to activity within a considerable area of the cortex with maximal changes in a central focal region.

Perhaps this theory can best be explained by referring it to an actual study. Courts' experiment (cited in 55) dealt with the effects of induced tension by the hand dynamometer on the patellar reflex. According to Meyer, when the patellar tendon is tapped, a motor channel is activated and thresholds of neurons in the vicinity of this channel are altered. But the input does not capture extensor neurons alone because of the overlap within the motor system and because of the lack of sharp definition within the input itself. Hence, the occurrence of extension is a statistical proposition; the input activates a population of cells in which there is greater representation of extensors than of flexors.

When the dynamometer is squeezed, another channel is activated and its extent is proportional to the force of the grip. Excitation is distributed to the vicinity of the leg channel where it trips off some of the neurons that are near, but not at threshold when hand activity is absent. It has no effect upon the cells that are triggered by the input for the knee jerk.

The differential recruitment of extensor neurons is a function of the changes brought about by the patellar input, because the contribution of distributed excitation from the hand is relatively minor and cannot be expected to have a selective effect. Now, it is apparent

from the spatial gradient of representation that the fringe regions adjacent to the leg channel are predominantly extensor in function. Similarly, the closer the cells are to the pathway, the more they are changed by the patellar input. Hence, distributed excitation from the hand channel fires more extensor than flexor neurons, and the result is an increase in jerk amplitude. Facilitation increases up to the point where as many flexor as extensor neurons are recruited. An inversion of the function takes place if and when distributed excitation fires the relatively remote pools of neurons that are dominated by flexor cells.

Pinneo (59) criticizes Meyer's theory because of the fact that the latter author fails to consider the involvement of the reticular activating system and level of arousal in muscle tension phenomena. In his study, Pinneo found that the electromyograph measure showed significant incremental changes corresponding to increasing values of induced tension. The demonstration of such widespread changes, Pinneo contends, would appear to cast strong doubt on any rationale limited to the skeletal-motor (or somatic) system. He concludes that Meyer's interpretation appears to suffer from this limitation. He further resolves that the results of his experiment definitely encourage the idea that the proprioceptive return from induced muscular tension produces widely generalized physiological effects.

From a different point of view, Adams (2) states that an increase in electromyograph recordings during work must be due to a recruitment of additional motor units in order for a subject to sustain the contraction. However, he asks how the activation of these new motor units comes about. Eason and Branks (20) suggest that it is cortically

aroused and represents the strength of subject's motivation in performing the task. In other words, as fatigue increases, activation rises to compensate for the subject's growing inability to cope with task demands. This interpretation is very similar to the position held by Malmo (52,53). He holds that muscular tension, whether induced experimentally by gripping a dynamometer while learning a task, is an index of activation that correlates with other physiological indices - like measures of heart rate and electrocardiograph. Malmo surmises that the covariation of these measures is a common function of the ascending reticular activating system of the brain, which could be the source of a generalized, nondirectional drive state. Malmo (53) suggests that muscular tension might function in a type of closed-loop feed-back circuit where tension states are induced experimentally or occur through learning; and these tension states in turn feed-back centrally, activate the reticular formation, and create activational level.

To account for the fact that neuro-muscular control deteriorates when a task becomes progressively complex, Eason and White (22) postulated that when tension level becomes too great, implicit muscular responses, irrelevant to the task being performed, compete for motor units actively involved in the task, and thereby reduce the amount of control the performer is capable of maintaining.

It would appear then that fatigue is caused by the rising effort of the performer when a complex task is being performed or the performer is working under the effects of induced muscular tension. These fatigue effects bring about a rise in the level of activation of the performer,

which in turn causes the activation of new motor units. However, these motor units are not necessarily the appropriate muscles necessary for a coordinated effort on the particular task. Hence, the firing of motor units extraneous to the demands of the task brings about a deterioration in performance.

An important point, similar to the arguments brought forward by Eason and White (22) concerning the relationship between tension level, level of activation and performance of a task, is brought out in a study by Eason and Branks (20). They postulate that whether tension level will correlate positively or negatively with performance quality on a given task is dependent upon the factor or factors responsible for a change in activation level. For example, if an increase in activation level is produced by factors extraneous to a task in which performance is being measured, then the resultant increase in tension may correlate negatively with performance on that task. But, if the increased activation reflects a greater degree of concentration on the task at hand, then tension level may correlate positively with performance.

An exception to the latter statement might be expected to occur only when one is already performing at his maximal skill level. In such case, no further improvement could occur, and there may actually be a decrement in performance (19).

Because of Duffy's two-dimensional behavior hypothesis, i.e., that behavior varies in both direction and intensity, one cannot tell from changes in tension level alone whether performance on a given task has improved or deteriorated, since performance quality is also dependent upon the direction of one's behavioral activity at the time.

An interesting approach to the relationship between induced muscular tension and performance, namely the inverted U relationship, is found when Duffy's two-dimensional behavior hypothesis is combined with Meyer's efferent neural interaction hypothesis. When pressure is applied to a dynamometer (Task A), proprioceptive stimulation arising from the hand and arm region may sufficiently excite the reticular activating system so as to produce an overall increase in the alertness level of the individual. When the amount of pressure is of low intensity and is not distracting, performance on a second task such as the pursuit rotor (Task B) might be improved as a result of the arousing effect of the proprioceptive input. But as greater amounts of pressure are exerted on the dynamometer, Task A will demand proportionately greater amounts of attention and effort, and even though level of activation is increased, performance on Task B will be impaired.

Effects Of Muscle Tension On Performance

A. Reaction Time

Very few studies completed in the past have dealt exclusively with the problem of the relationship between different pre-induced muscular tensions and reaction time. Those that have been published introduce variables incompatible to the purpose of this thesis. Therefore in most cases the studies presented will offer indirect, but substantial evidence that supports the activation hypothesis.

Freeman and Kendall (29) studied the effect upon reaction time of muscular tension at various preparatory intervals. Using ten subjects, and twenty-five trials with foreperiods of two, four, eight and ten seconds, they found that the mean of individual reaction times showed

less variation under tension than it did under no tension. For a four second interval, tension markedly facilitated reaction time in all subjects, while for the two second interval, no tension was found to facilitate reaction. The differences between tension groups and control groups were significant at the five percent level of significance. These results may be taken as concrete evidence in support of the relationship between muscular tension and reaction time.

In a similar study, Teichner (72) obtained results which conflicted with those of Freeman and Kendall's. Using foreperiods from two to eleven seconds and induced tension from five to thirty-five pounds, Teichner found, with forty-five subjects, that the greatest speeds were achieved with the lighter loads. He suggested a possible worst load at twenty-five pounds. No mention was made of the combination of foreperiod and tension load, however, he mentioned that no significance could be determined for any part of the study. In another section of the same study, using a constant foreperiod of either two, five, eight, or eleven seconds and tension loads of five, fifteen, twenty-five or thirty-five pounds, he found that with forty-eight subjects there was an increase in response speed as the load was increased ($F=7.57$; $P \leq .01$). Teichner concluded that his results indicated reaction time to be inversely related to magnitude of tension.

Kagan (37), using two subjects and thirty-six blocks of trials with forty-eight reaction times in each block, discovered that some evidence exists for speed-up in response when a low resistance has to be overcome and the muscular tension in the response group is increased slightly. More specifically, he found that for relatively low levels

of post-tension (defined as the force required to be overcome in reacting), from one-quarter to one pound, and a relatively low increase in the pre-tension level (defined as the "holding force" before stimulus is presented), from one-quarter to one pound, tended to produce a decrease in reaction time (significant for one subject at .05 level of confidence and not significant for the other subject). It might be mentioned that the foreperiods were randomly varied between two and three and one-half seconds.

Schlosberg (66) carried out an investigation in which he tried to duplicate Freeman and Kendall's work (29). Schlosberg set up a portable reaction timer, with a built-in device to vary the foreperiod. One student was then requested to take a hundred sets of readings on herself, sampling all hours of the day from before breakfast to bedtime. Each session included twenty simple auditory reaction times. An inverted U relationship was found to exist between simple auditory reaction time and skin resistance. Graphic results of the experiment can be seen in Woodworth and Schlosberg's textbook (77, p.177).

In a similar study, Kennedy and Travis (39) used thirty-two subjects, and had them react to a visual stimulus at varying degrees of muscular tension while performing a tracking task. Muscle tension was measured in terms of muscle potential output. At least one-hundred reaction times were taken at each of several levels. They discovered that, on the average, reaction times became progressively slower as the tension level became progressively lower, and that variability in reaction time became greater with lowering tension levels. No statistical treatment of the data was given. In other studies (70,71), the

same authors obtained similar results.

Lansing, Schwartz and Lindsley (46) carried out a study that resembled those of Travis and Kennedy, but this time the electroencephlagraph was utilized as an indicator of alertness. Visual reaction times were measured in nine adult subjects under two general conditions - non-alerted and alerted. From two-hundred to five-hundred reaction times were obtained on each subject. A buzzer was sounded before presentation of the stimulus in the alerted condition, whereas no buzzer was sounded in the other. A highly significant difference ($P \leq .01$) was obtained for the overall mean between the non-alerted state (.280 msecs.) and the alerted state (.225 msecs.).

A study that failed to verify the curvilinear relationship between tension and performance was reported by Kling and Schlosberg (42). They reported that twenty-two subjects underwent from two to fifty-seven sessions using reaction time as the criterion task and skin conductance as the measure of tension. They concluded, without giving statistical results, that no subject even approached the curvilinear relationship expected.

B. <u>Muscular Tension And Performance On The Pursuit Rotor</u>

Like the previous review, this section presents very few studies that deal explicitly with the purpose of this thesis. Most results offer indirect support for the activation hypothesis, but as before they also demonstrate a strong relationship between activation level and motor performance.

Courts (9) carried out possibly the most pertinent study in relation to the present problem. Six groups of thirty-two subjects

squeezed hand dynamometer tensions of one-eighth, one-quarter, three-eighths, one-half, five-eighths, and three-quarters of maximum strength while performing pursuit rotor. Subjects had fifty trials of twenty seconds in length with a forty second rest period between trials. Courts found that the optimal tensions for performance were one-eighth and one-half of maximum strength. These tensions, when combined with the others, gave the expected U-shaped relationship.

Eason and White (21) carried out a similar study to that of Courts. Using forty-eight subjects, with one minute trials and ten second rest periods between each of the twenty trials, they had their subjects perform with zero, five and ten pounds of weight hanging from their wrists. Their results, although not significant, showed that performance level is inversely related to weight magnitude, while muscular tension level, measured by the electromyograph, is positively related to the magnitude of the weight. Perhaps the authors did not receive the facilitative effect of induced muscle tension because of their large increments of weight (i.e., zero, five and ten pounds).

Another study, resembling the previously two mentioned ones, is an experiment by Kling, Williams and Schlosberg (44). Although they did not use induced muscle tension, they utilized the effect obtained from massing of practice. In essence, they hypothesized that massed practice would produce muscular tension that could be measured through the galvanic skin response. The authors utilized fifty-two subjects, and used two work periods of either ten or fifteen minutes in length so that all subjects received an equal amount of time on the pursuit rotor. In their results a general pattern, revealed by the

simultaneous recording of skin conductance and pursuit score, indicates that both pursuit proficiency and conductance show an over-all rise from the start to the end of the experiment. These results were contrary to what the authors had expected. They had assumed, according to the inverted U hypothesis, that the level of tension would build up higher than the optimal level toward the end of each practice period. This excess tension would impair efficiency of performance, thus accounting for the levelling off of the performance score. An obvious conclusion, that could be drawn from this experiment, is that the experimenters erred in their choice of length of practice. The practice they gave their subjects never allowed tension to build up past the optimal point, thus no decrement in performance could be obtained.

Negative results, in relation to the inverted U hypothesis, were again achieved in a study by Bell (5). The experiment consisted of 216 subjects, broken up into nine groups, with each group having thirty-twenty second trials on the pursuit rotor. The subjects were given varying amounts of weight to hold with their non-preferred hand along with varying amounts of motivating instruction. These conditions varied from no weight and no instructions to maximum weight and maximum instructions. The amount of the weights or the type of instructions were not given in the article. From the results, no significant differences between subjects were reported. The hypothesis offered by Bell for not confirming the inverted U hypothesis was that the initially high motivational state of the subjects, due to the incentive provided by this particular perceptual motor task, completely cancelled out any effects the weights or the instructions had on performance.

C. Muscular Tension And Performance On Other Tasks

As in the last two areas, there are only a few specific studies that apply to the present problem. The others, although supporting the inverted U hypothesis indirectly, just serve as further evidence that the area of activation could prove to be fruitful in some aspects of psychological research.

The first study in this section deals with the effects of muscle tension on mirror drawing. Bartoshuk (3) measured the general tension of his twenty-five subjects by an electromyograph as they were drawing concentric circles while looking through a mirror. The major finding of the study was that the marked individual differences in gradient slope of the electromyograph recordings are directly related to individual differences in quality of performance (P from .001 to .03). In his discussion, Bartoshuk pointed out that it is interesting to consider the non-linear relation seen between performance and slope of electromyograph gradients. Within the limits of his experiment, it was demonstrated, that beyond a critical value, performance does not benefit from further increases in gradient slope. In fact, he stated, there is a suggestion that for best performance the gradient slope has an optimal value, and for slopes in excess of this optimum, performance may be slightly impaired.

Howell (35) studied the effect of emotional tension on total time (reaction time plus movement time) on a ball snatch apparatus. Using fifty subjects, Howell had each perform fifteen trials under conditions of no shock; then had them do ten trials under conditions of shock. Next, by subjective judgment the total group was broken up

into two groups: the extremely tense, and the relaxed. The mean improvement in performance for the tense group was 0.334 seconds, and for the relaxed group was 0.239 seconds. The t-ratio of 2.07 was statistically significant. One could conclude from these findings, that tension actually facilitated performance in this type of task.

The effects that three conditions of tension (namely, moderately relaxed, natural, and moderately tensed) had on ball throwing was studied by Russell (60). Using 300 trials, he found that when his forty subjects subjectively relaxed, tensed, or tried to remain natural, the natural condition was significantly ($P \leq .01$) better than the tensed. The natural condition was also slightly more efficient than the relaxed condition, however this factor was not significant. He concluded from his findings, that the degree of accuracy and the degree of tension were inversely related.

Klein (41) studied the effects of tension on performance in a slightly different manner, by using the technique of "breakdown" of work. He defined breakdown of work as the distance between a suspended weight and its baseline in a paced repetitive weight lifting task. He implied that this breakdown of work may have broad implications for the phenomenon in stressful situations, of "freezing" at the controls in the operation of motor vehicles or aircraft. To study this, he measured the relationships between muscle action potentials and the amount of breakdown in a finger ergographic task. The relationship between breakdown and muscle action potentials for all of his thirteen subjects was significant between the five percent and two percent levels of confidence. The interpretation of these results was that an increase

in muscle action potentials was associated with an increase in breakdown of work. From his results, Klein reasoned that too much or too little tension may be equally deleterious to performance. He further suggested that for every task optimal tension levels might exist above or below which performance in skilled motor tasks is dependent upon the extent to which the performer manifests these optimal levels on any given occasion.

Ryan (62) studied the relationship between motor performance on a stabilometer and arousal. Splitting his forty subjects into two groups, those of high arousal and low arousal chosen on the basis of skin conductance measures taken during twelve trials on the stabilometer, he found that the high arousal group performed significantly better than the low arousal group, both early (trials one to six) and late (trials six to twelve) in practice ($F=8.98$ and 10.30 respectively). His conclusion was that the data indicated a relationship between arousal, as measured by skin conductance, and performance on a gross motor skill.

Failure to find any significant findings between tension loads and performance on a two-handed matching task was reported by Adams (1). Using 160 subjects, and having them induce tension by pressing zero, ten, twenty and thirty pounds to the floor with their feet, Adams stated that tension did not serve to differentiate the three groups using the tensions from the group using zero pounds of tension. In his study, Adams stated that thirty pounds was used as a maximum tension, because anything over that amount would distract the subject from the main task. He also mentioned that his results might be explained by the fact that the induced tension was not close enough to the responding

body members to produce an overlap of neural impulses in the motor pathways, which must occur before a facilitative effect takes place.

Effects Of Muscle Tension On Simple And Complex Tasks

In general it is believed that externally induced tension will facilitate or impede performance, depending on the degree of difficulty of the task. Usually, on a relatively easy motor skill, induced tension will facilitate performance; whereas on a more difficult motor skill, tension will impair performance. However, as has been already stated, the difficulty of the task is not the only parameter that one has to consider when evaluating the effect of tension on performance. This section of the review will deal explicitly with task difficulty, and with performance under induced tension. Again, as in the past sections, there are very few studies completed in this area that deal exclusively with the problem of this thesis.

Ryan (63), using the stabilometer and varying the center of rotation to make the task simple or difficult, induced tension by introducing shock. His study consisted of 120 subjects, performing twelve trials each. The results indicate that no difference was noted between the experimental and control groups for the easy task. For the difficult task, the experimental group was significantly poorer than the control group ($t=2.25$ at the five percent level of confidence). Ryan concluded that these findings were in agreement with the hypothesis that tension will impair performance on a difficult task. No explanation was given as to why facilitation of the easy task did not occur.

Using finger oscillation, mirror-drawing, intensity limen for

touch, eyelid reflex and mental arithmetic, Freeman (27) had ten subjects perform the prescribed tasks, while inducing muscular tension by pressing from zero to eighty pounds to the floor with their feet. The results show that increments in tension are facilitative for finger oscillation, the optimal loading occurring late or not at all. The optimal loading point occurred earlier for mirror-drawing than for the simpler task of finger oscillation. In general, Freeman suggested that the more complex the performance, the earlier will the tension increment show inhibitory effects.

Gregg (31), using twelve subjects, studied the effect of placing a sixty-seven pound pack-board on the subject's back while performing the tasks of hand steadiness and finger tapping. The scores for the steadiness task suggest that the pack-board load adversely affected performance ($P \leq .01$). However, in the case of the tapping task, improvement was found with increased muscle tension. In general, Gregg concluded that increases in generalized tension for the difficult task (hand steadiness) accompany a performance decrement, while improvement in tapping (simple task) may be accompanied by an increase in generalized tension.

In a study involving pursuit rotor with four different target sizes, Eason (19) had eight subjects track the four different target sizes twice a day for eight days. There were eight trials per day with three and one-half minute work periods and a two minute rest between trials. Analysis of the data revealed that pursuit rotor scores were significantly ($P \leq .01$) affected by target size, with the tension level of the muscle showing significant changes from different target sizes ($P \leq .01$). In Performance efficiency, an inverted U shaped function was obtained ($P \leq .01$).

CHAPTER III

METHODS AND PROCEDURES

Subjects

The subjects were randomly chosen from the freshman population of the 1965-66 academic year at the University of Alberta at Edmonton. Ninety-two subjects were selected by employing a table of random numbers.

Experimental Design

A basic split plot design was used. Tension levels were assigned within subjects and the two tasks were assigned between subjects. Each one of the ninety-two subjects was randomly assigned to one of the two tasks. The five tension loads (i.e., zero, five, ten, fifteen, and twenty pounds) were also randomly assigned to each subject. Since a repeated measurements design was used each subject performed eight trials under each tension level. The zero pound tension level was tension free and served as a control condition. At each specific tension level all subjects were given one practice trial before beginning the experimental trials.

All subjects completed the required forty trials (eight trials under all five tension levels) at one experimental session. To offset any possibility of fatigue accumulating during the course of the experiment and effecting performance, the experimenter made certain that each subject rested after each tension level for at least one minute. Further, after completing the tension levels of ten, fifteen, or twenty pounds each subject would stop for a rest and be replaced

by a second subject. By testing two subjects concurrently in this fashion, each subject had at least two rest periods while completing the series of tests. The second subject was always in a separate room away from the experiment proper.

Apparatus

The following apparatus were used:

1. A Reaction Time - Movement Time ball snatch apparatus (Figure I). A ball was hung on a string, the lower end of which was attached to the baseboard while the upper end terminated in a flat piece of steel. This piece of steel was held in place by two magnets which allowed an electric current to operate when the steel was in place. When the ball was grasped the circuit was opened. In this way a "movement time" could be obtained which was the time required for a subject to grab the ball after he had reacted. The main box of the apparatus contained a specially designed reaction lever that allowed the experimenter to vary the tension required to push the bar down to the horizontal. This was achieved by placing, under the reaction bar, a hard steel coil which could be raised or lowered by a special screw device. Two microswitches were placed under the reaction bar. One operated an orange warning light while the other opened a circuit to the chronoscope that was used to obtain reaction time. The microswitch that controlled the warning light was set one-eighth of an inch above the other one. The reason for this will become clear in a later section.

The above mentioned apparatus, taken as a whole, represented the complex task. For the simple task the extension holding the tennis ball was covered.

2. Two chronoscopes which could be read to 1/100 of a second.

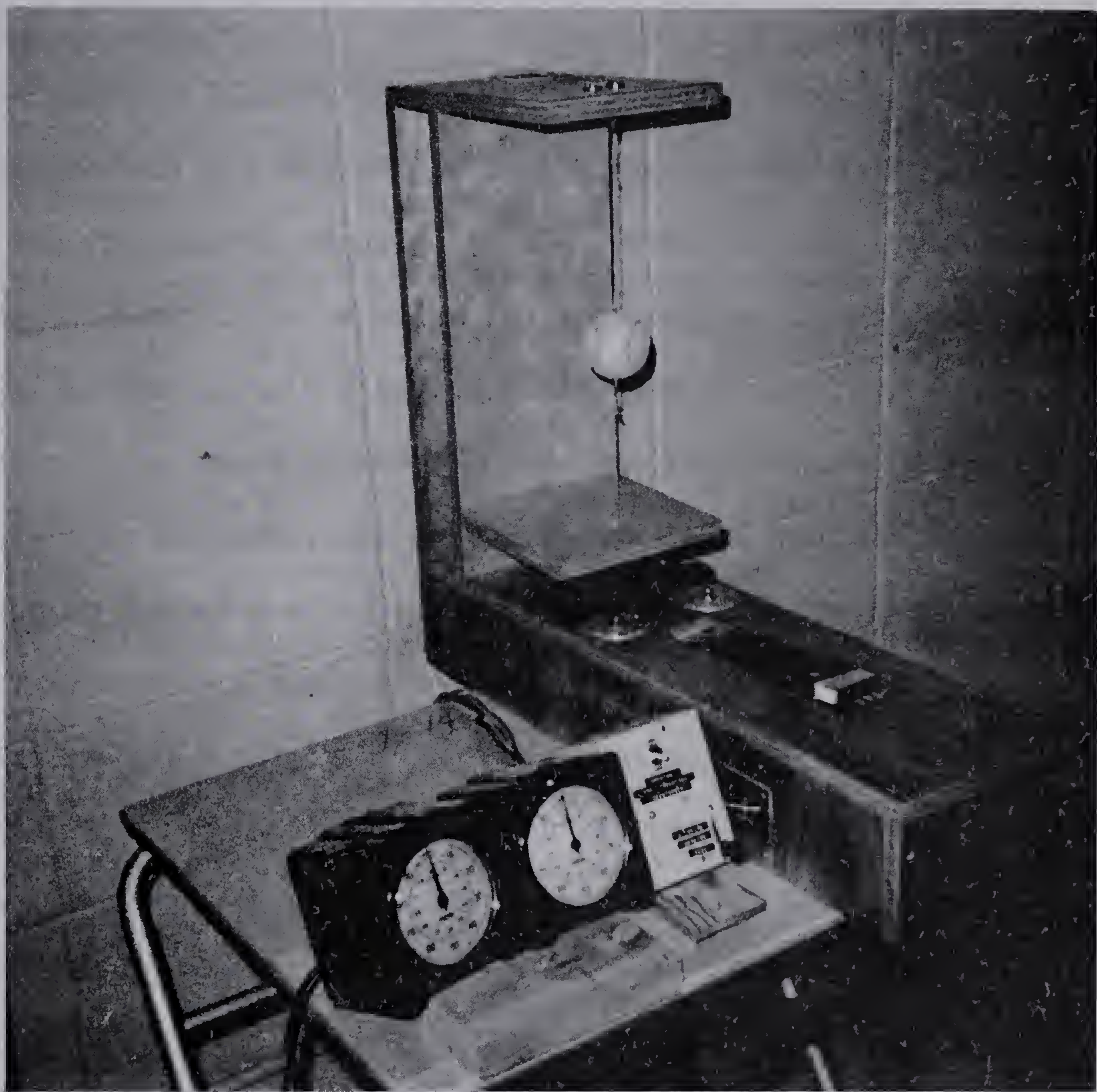

FIGURE I. REACTION TIME-MOVEMENT TIME APPARATUS

3. A specially designed control panel, for the above apparatus, which allowed the experimenter to control the operation of the apparatus.

Methods And Procedures

Standardized procedures for all subjects were as follows: each subject was seated in front of the apparatus. He was then requested to place his first three fingers, of his preferred hand, near the end of the reaction bar. The position for the correct placement of the fingers was indicated by a piece of white tape on the bar.

To keep the angle of the arm constant for the length of the test and for all subjects, the experimenter requested the subject to keep his upper arm at a right angle to that side of the body and in a straight line with his back. To control the position of the apparatus in relation to the position of the body, the tip of the subject's preferred shoulder was placed in line with the midpoint of the apparatus.

When the correct position had been obtained the following procedure was used for all tension levels, except that of zero pounds: the subject, on a signal from the experimenter, pressed the reaction bar down to the horizontal until a microswitch was closed and a yellow warning light was activated. The appearance of the yellow light informed the subject that he was to hold the reaction bar in that exact position until the stimulus light appeared (i.e., a white light immediately to the right of the warning light). This stimulus light was presented, randomly, one to four seconds after the warning light appeared. The preceding procedure enabled the experimenter, by manipulating the distance that the reaction bar had to be pressed down against a solid coiled spring, to induce a resistance equivalent to

five, ten, fifteen or twenty pounds, i.e., the longer that the distance of the bar was from the horizontal a more proportional amount of effort was required from the subject to press the bar down to bring the warning light on.

For zero pounds of tension the subject was instructed to only rest his fingers lightly on the bar and wait for the yellow light to be presented. The reaction bar was in such a position that the micro-switch, which controlled the yellow light, was closed and hence could be presented by the experimenter through the main control panel. The experimenter, when ready to start the test at this particular tension level, warned the subject by saying "ready" on each trial and then immediately presented the yellow light. One to four seconds later the white light or stimulus light was presented.

From this point, the manner in which the subject reacted to the stimulus light varied according to which task was being performed. In the simple task, with the tennis ball covered, all that was required of the subject was that he react immediately, upon perceiving the stimulus light, by pressing the reaction bar down about one-eighth of an inch as fast as possible. In so doing, the subject operated a micro-switch that opened a circuit and stopped the reaction time chronoscope. Hence, the experimenter had a measure of reaction time.

The complex task was identical except with the additional component of a ball snatch. With the tennis ball uncovered the subject, after reacting as in the simple task, was required to grab the ball as fast as he could. This involved making a movement of about twelve inches. Grabbing the ball disconnected an electrical circuit and

enabled the experimenter to obtain a score for movement time.

Statistical Hypothesis

The null hypotheses for this investigation were:

1. There was no difference in reaction time among the five tension levels within each task.

2. There was no difference in reaction time between the two tasks for any one particular tension level.

3. There was no difference in movement time among the five tension levels within the complex task.

CHAPTER IV

RESULTS AND DISCUSSION

Results

Probability Levels For all statistical analysis the probability level was at the five percent level of confidence for a two tailed test.

Comparison Of The Simple And Complex Tasks In Reaction Time

Reliability[1] Odd-even reliability coefficients were computed for all tension levels in both tasks. The data yielded the following results:

TABLE I

RELIABILITY OF SIMPLE AND COMPLEX TASKS AT ALL TENSION LEVELS[a]

Tension Level	N	Simple Task	Complex Task
0 Pounds	46	.88	.88
5 Pounds	46	.85	.92
10 Pounds	46	.91	.90
15 Pounds	46	.93	.88
20 Pounds	46	.89	.88

[a]All reliability coefficients were statistically significant at the .05 level of confidence.

[1]The chronoscope that was used for reaction time gave a variable error of .005 seconds and a constant error of .006 seconds.

The above results were those that were already corrected by the Spearman-Brown Correction Formula. The Z' transformation (24:79) was used to test the significance of the difference between the largest and smallest coefficients in both tasks. A Z of 1.31 and .99 was obtained for the simple task and complex task, respectively. In order to reach significance at the five percent level of significance, a Z of 1.96 was required. The difference that was obtained when the largest coefficient was compared to the smallest, regardless of task, also failed to reach significance ($Z=1.31$, $P<.05$).

Mean Reaction Times. Performance on the two tasks yielded the results indicated in Table II. Mean reaction time for each tension level was obtained by averaging the eight trials for each of the forty-six subjects. An F Max test (76:93) to test the hypothesis of equal population variances was administered to the variances. A value of 2.33 for F Max was obtained with a required critical value for F Max .95 (10,46) = 2.86. Thus the hypothesis of equal population variances was not rejected.

TABLE II

MEAN REACTION TIMES AND STANDARD DEVIATIONS FOR THE SIMPLE AND COMPLEX TASKS (SECS.)

Tension Level	Simple Task	S.D.	Complex Task	S.D.
0 Pounds	.205	.026	.209	.034
5 Pounds	.207	.030	.211	.027
10 Pounds	.210	.034	.210	.028
15 Pounds	.205	.033	.212	.030
20 Pounds	.211	.039	.223	.036

<u>Analysis of Variance</u>. A basic split plot design that employed repeated measurements was used in which the main effects (tasks and tension levels) and the interaction between them could be examined. Table III is a summary of this analysis.

TABLE III

ANALYSIS OF VARIANCE FOR REACTION TIMES

Source of Variation	SS	d.f.	MS	F	P
Tasks	.003478	1	.003478	—	
Ss(Tasks)	.317567	90	.003529		
Tension Levels	.005653	4	.001413	3.47	<.025
Tasks X Tension Levels	.001522	4	.000381	—	
Ss(Tasks) X Tension Levels	.144275	360	.000401		
Total	.472495	459			

Following an analysis of variance, further statistical analysis is usually limited to those effects in which the overall F was significant. Such was not the case in this experiment. Winer states (76: 206): "The specific comparisons which are built into the design or suggested by the theoretical basis for the experiment can and should be made individually, regardless of the outcome of the corresponding overall F test." Therefore a complete description of the experimental findings was presented, even though some of the tests on parts of non-significant overall variation could have been unduly subject to type I error.

For the main effect of tasks, the overall F of less than one indicated that there was no significant difference between the two tasks,

in reaction time, when all tension levels were averaged together. This conclusion was reinforced by finding a F of also less than one when orthogonal coefficients (24:145) were applied to the reaction time sums for the two tasks.

Range Test On The Overall Tension Levels. That there was a significant difference between tension levels when the two tasks were averaged together was denoted by the significant F ratio of 3.47 for the main effect of tension levels. To ascertain the exact nature of these differences a range test (24:136) was applied to the means of the tension levels when the tasks were averaged together. From this analysis (Table IV) it is apparent that the reaction time for the tension level of twenty pounds was significantly slower than all other times. All other differences failed to reach significance.

TABLE IV

DUNCAN'S NEW MULTIPLE RANGE TEST FOR OVERALL TENSION LEVELS

Means	0 Lbs. .206938	15 Lbs. .208478	5 Lbs. .208880	10 Lbs. .209826	20 Lbs. .216978	Shortest Significant R
0 Lbs.		.001540	.001942	.002888	.010040[a]	R_2 = .005785
15 Lbs.			.000402	.001348	.008500[a]	R_3 = .006090
5 Lbs.				.000946	.008098[a]	R_4 = .006296
10 Lbs.					.007152[a]	R_5 = .006447
20 Lbs.						

[a]Significant at the .05 level of confidence.

Trend Analysis of the Overall Tension Levels. The a priori assumption that reaction time would follow an inverted U relationship with tension levels suggested a trend analysis (24:239) of the overall tension levels (Figure II). The results of this analysis (Table V) suggested that the data could best be explained by a linear trend ($F = 8.89$, $F_{.05}(1,360) = 3.86$). That is, as the tension level increased, reaction time tended to become slower. This conclusion was strengthened by the fact that non-significant F's were obtained for the quadratic and cubic trends.

The final portion of variance examined in the analysis of variance was that due to the interaction between the tasks and the tension levels. The overall F (Table III) signified a non-significant interaction.

Trend Analysis Of The Tasks And Tension Levels Interaction. In order to test the hypothesis that reaction time followed an inverted U relationship with tension levels and further that the simple task would have a shallower curve than the complex task, a trend analysis of the interaction was computed (24:240). Both the linear and quadratic components of the interaction were examined (Table VI). It was apparent that neither F came close to the required five percent critical limit. This implied that there were no statistically significant differences in the linear and quadratic trends between tasks. The latter result (i.e., quadratic trend) resulted in failure to reject the aforementioned hypothesis.

Range Test On The Simple And Complex Task Means. To determine if the mean performances under all five tension levels differed from

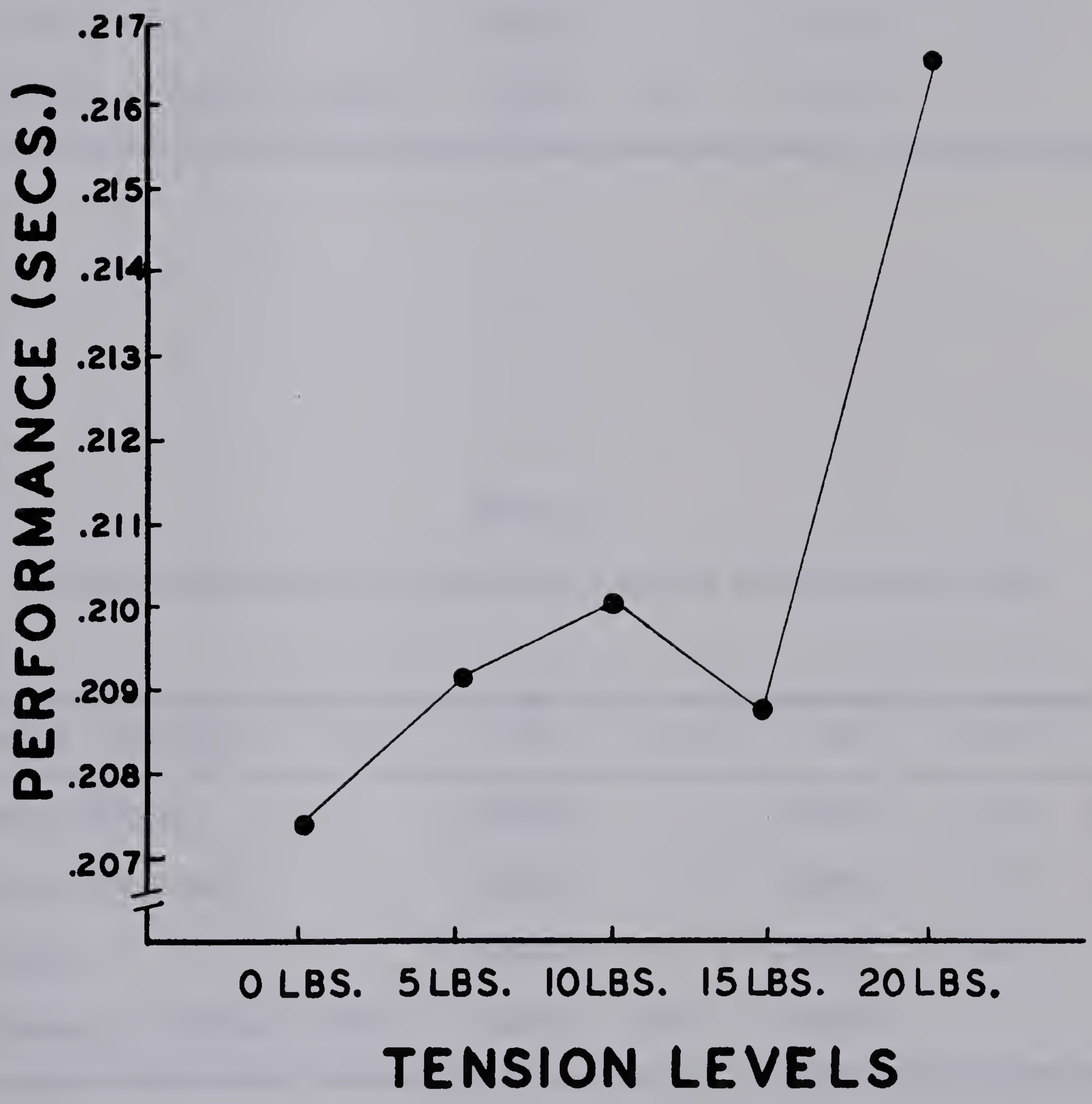

FIGURE II PROFILE OF THE MEANS FOR REACTION TIMES WHEN TASKS ARE AVERAGED TOGETHER

TABLE V

TREND ANALYSIS OF THE OVERALL TENSION LEVELS

Source of Variation	SS	d.f.	MS	F	P
Linear Component	.003564	1	.003564	8.89	<.005
Quadratic Component	.000768	1	.000768	1.92	<.250
Cubic Component	.000237	1	.000237	—	
Ss(Tasks) X Tension Levels	.144275	360	.000401		

TABLE VI

TREND ANALYSIS OF THE TASKS AND TENSION LEVELS INTERACTION

Source of Variation	SS	d.f.	MS	F	P
Linear Component	.000623	1	.000623	1.55	<.250
Quadratic Component	.000565	1	.000565	1.41	<.250
Deviations	.000334	1	.000334	—	
Ss(Tasks) X Tension Levels	.144275	360	.000401		

one another a range test was run on the means of each task (Tables VII and VIII). The hypothesis of no differences between the means was not rejected for the simple task. However, the same test run on the complex task resulted in the mean reaction time for twenty pounds being significantly slower than all other mean reaction times. No other differences proved significant. Interpreting this result in light of the significant difference obtained in the range test for the overall means (Table IV), it would seem that the latter result was primarily due to the effect of the slow time at twenty pounds of tension for the complex task.

Individual Comparisons. Winer (76:208), while employing an F statistic, outlined a procedure for making individual comparisons. This statistic was used in the present study to test the significance of the differences between tasks for each tension level (Table IX) From inspection of Figure III it is evident that the complex task had slower mean reaction times for all tension levels. However, only one difference, that at twenty pounds, reached significance. The difference at fifteen pounds approached significance but fell slightly short. These results indicated that at the low tension levels both tasks produced similar reaction times, but as tension was increased the complex task was affected more adversely and reaction time became slower when compared to the simple task (refer to Figure III). This finding is in direct support of the hypothesis that the simple task would be less affected by tension than would the complex task.

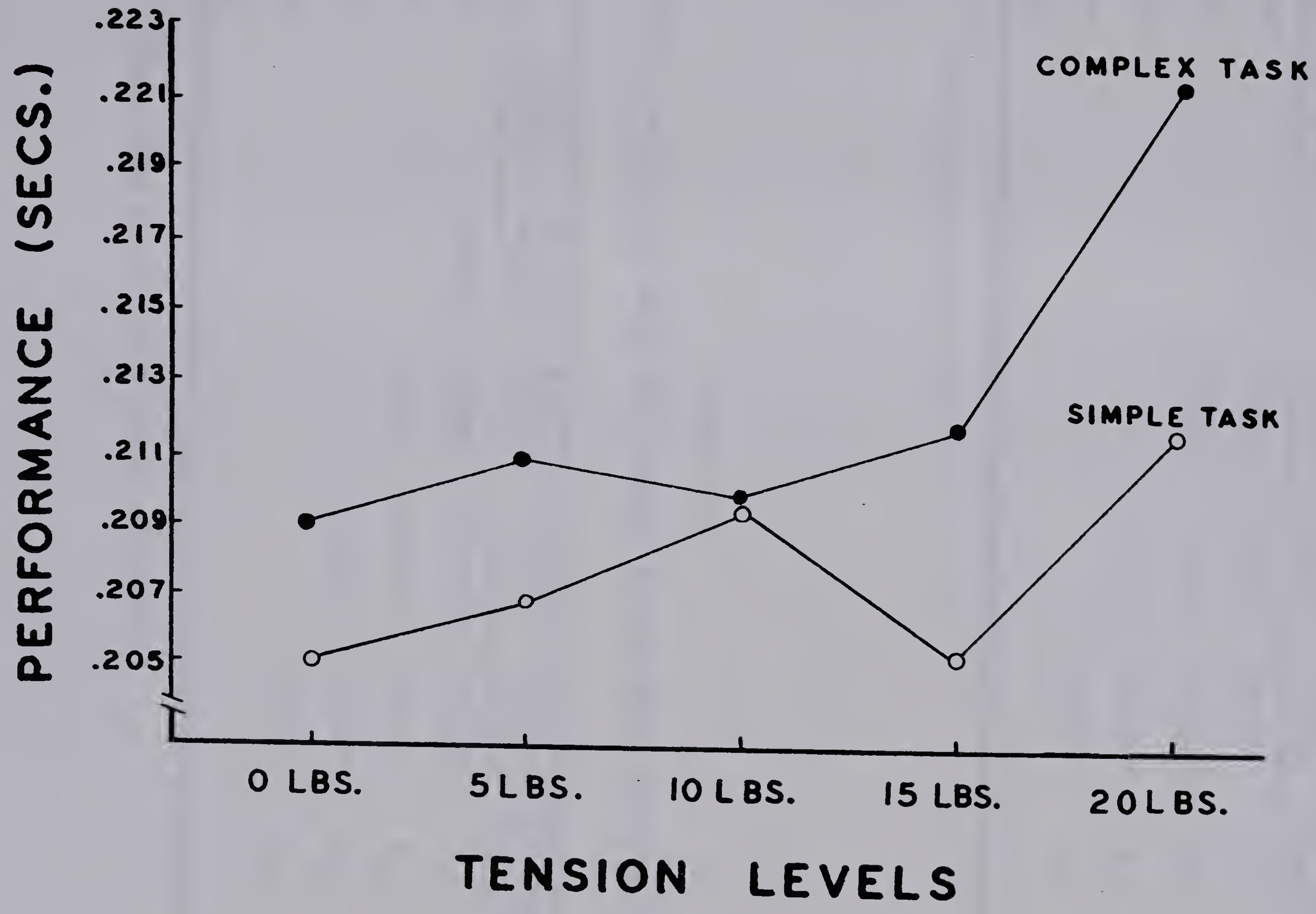

FIGURE III PROFILE OF THE MEANS FOR REACTION TIME SHOWING THE INTERACTION OF THE TWO TASKS WITH TENSION LEVELS

TABLE VII

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE SIMPLE TASK

Means	15 Lbs. .204760	0 Lbs. .204782	5 Lbs. .206608	10 Lbs. .209760	20 Lbs. .211434	Shortest Significant R[a]
15 Lbs.		.000022	.001848	.005000	.006674	R_2 = .0080
0 Lbs.			.001826	.004978	.006652	R_3 = .0080
5 Lbs.				.003152	.004826	R_4 = .0089
10 Lbs.					.001674	R_5 = .0091
20 Lbs.						

[a]Significance level = .05.

TABLE VIII

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE MEANS OF THE COMPLEX TASK

Means	0 Lbs. .209086	10 Lbs. .209891	5 Lbs. .211152	15 Lbs. .212195	20 Lbs. .222521	Shortest Significant R
0 Lbs.		.000805	.002066	.003109	.013435[a]	R_2 = .0080
10 Lbs.			.001261	.002304	.012630[a]	R_3 = .0080
5 Lbs.				.001043	.011369[a]	R_4 = .0089
15 Lbs.					.010326[a]	R_5 = .0091
20 Lbs.						

[a]Significant at the .05 level of confidence

TABLE IX

DIFFERENCES BETWEEN TASKS AT THE FIVE TENSION LEVELS[a]

Tension Level	Difference	$(\text{Difference})^2$	F	P
0 Lbs.	.198	.039204	1.06	>.10
5 Lbs.	.209	.043681	1.18	>.10
10 Lbs.	.006	.000036	—	
15 Lbs.	.342	.116964	3.17	<.10
20 Lbs.	.510	.260100	7.05	<.025

[a]Standard error of a comparison = .036870, d.f. = 1,360.

Comparison Of The Movement Time Means In The Complex Task

Reliability[1]. As in reaction time, odd-even reliability coefficients were calculated for all tension levels (Table X). All coefficients were corrected by the Spearman-Brown Correction Formula.

TABLE X

RELIABILITY OF MOVEMENT TIMES FOR THE COMPLEX TASK[b]

Tension Level	N	R
0 Lbs.	46	.96
5 Lbs.	46	.96
10 Lbs.	46	.95
15 Lbs.	46	.98
20 Lbs.	46	.96

[b]All coefficients were significant at the .05 level of confidence.

[1]The chronoscope that was used to measure movement time produced a constant error of .003 seconds and a variable error of .005 seconds.

The Z' transformation (24:79) was applied to the difference between the largest and smallest coefficient with the result of no significant difference ($Z = 1.80$, $Z_{.05} = 1.96$).

Mean Performances In Movement Time For The Complex Task. Table XI illustrates mean movement times and standard deviations for all tension levels. All means were averaged over 46 subjects with each subject having received eight trials. To test the hypothesis of equal population variances an F Max test (76:93) was computed. The resulting F of 1.60 with 5 and 46 d.f. failed to exceed the critical value of 2.33 at the five percent level of significance. Hence the above hypothesis was not rejected.

TABLE XI

MEAN MOVEMENT TIMES AND STANDARD DEVIATIONS
FOR THE COMPLEX TASK (SECS.)

Tension Level	N	Mean	S.D.
0 Lbs.	46	.516	.102
5 Lbs.	46	.539	.097
10 Lbs.	46	.549	.088
15 Lbs.	46	.565	.119
20 Lbs.	46	.582	.109

Analysis Of Variance For Movement Time In The Complex Task. To analyse variation in movement time a randomized blocks design, employing subjects as blocks, was used (24:158). The obtained F (Table XII) resulted in rejection of the hypothesis that mean movement time per-

formances were equal for all tension levels.

TABLE XII

ANALYSIS OF VARIANCE FOR MOVEMENT TIME

Source of Variation	SS	d.f.	MS	F	P
Tensions	.118102	4	.029525	9.43	<.005
Blocks	1.853830	45			
Residual	.563446	180	.003130		
Total	2.535378	229			

Range Test On The Movement Time Means. The exact nature of the differences among the means, as was indicated by the significant F value in the analysis of variance, was determined by using the Duncan's New Multiple Range Test (24:136). From inspection of Table XIII it was apparent that the only differences that were not significant were those between fifteen and twenty pounds, ten and fifteen pounds, and five and ten pounds. All other differences were significant at the five percent level of significance.

TABLE XIII

DUNCAN'S NEW MULTIPLE RANGE TEST APPLIED TO THE MOVEMENT TIME MEANS

Means	0 Lbs. .515717	5 Lbs. .539869	10 Lbs. .549021	15 Lbs. .565326	20 Lbs. .582478	Shortest Significant R
0 Lbs.		.024152[a]	.033304[a]	.049609[a]	.066761[a]	R_2 = .01918
5 Lbs.			.009152	.025457[a]	.042609[a]	R_3 = .02031
10 Lbs.				.016305	.033457[a]	R_4 = .02105
15 Lbs.					.017152	R_5 = .02160
20 Lbs.						

[a]Significant at the five percent level of confidence.

Trend Analysis Of The Movement Time Means. The trend that the movement time means followed (Figure IV) through the five tension levels, was calculated by using the trend analysis suggested by Edwards (24:239).

Table XIV indicated that the linear component was highly significant. This implied that the best description of the trend that the movement time means followed was a linear relationship. In other words, as tension increased movement time increased linearly. No need was evident to test for the quadratic trend since over ninety-eight percent of the variation due to tension levels was accounted for by the linear trend. This latter fact was supported by the non-significant F that was obtained for deviations from linearity.

TABLE XIV

TREND ANALYSIS OF THE MOVEMENT TIME MEANS

Source of Variation	SS	d.f.	MS	F	P
Linear Component	.116260	1	.116260	37.14	<.005
Deviations From Linearity	.001842	1	.001842		
Residual	.563446	180	.003130		

Discussion

Reliability Of Reaction Time And Movement Time. In a recent dissertation Kerr (40) reviewed several studies that had reported reaction time and movement time reliabilities. These particular studies disclosed that reaction time reliabilities varied from .89 to .93, while those of movement time were between .93 and .98. In

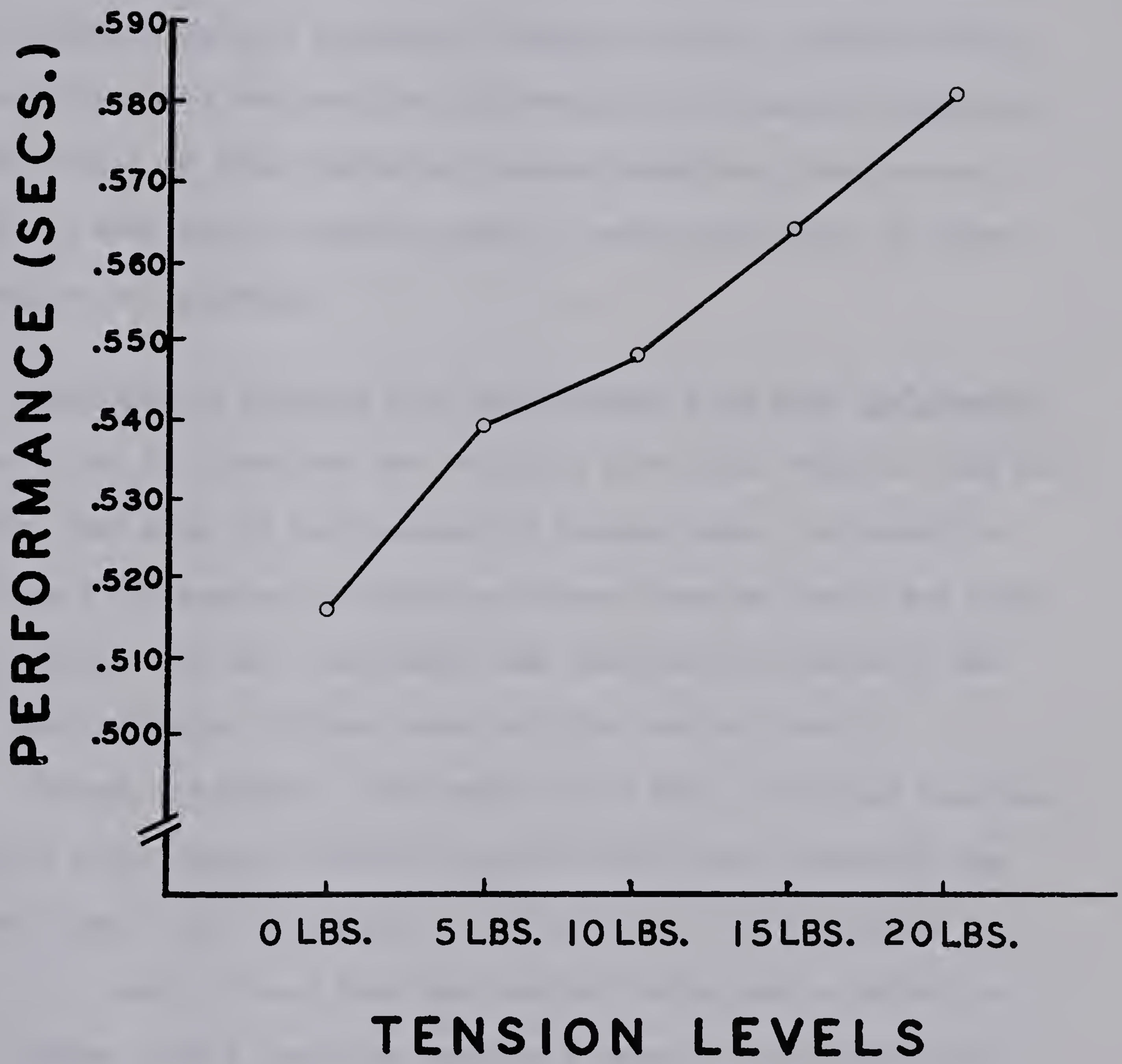

FIGURE IV. PROFILE OF THE MEAN MOVEMENT TIMES FOR THE COMPLEX TASK.

general movement time reliability coefficients were found to be higher than those of reaction time. The coefficients that were obtained in the present study suggested a great deal of similarity to those of the above and it appeared that tension did not have any differential effect on reaction time and movement time reliabilities.

Further, it can be noted that the reaction time and movement time reliabilities were relatively constant over all tension levels. This would seem to indicate that differences in variation between people in respect to total variation remained relatively stable even though, in some cases, tension served to reduce efficiency in speed of reaction and movement.

<u>Variation Of Reaction Time And Movement Time Mean Performances</u>. Tables II and XI illustrate the variation about each reaction time and movement time mean for each respective tension level. Although no significant differences in variation between tension levels and tasks were reported, the data warranted some speculation because of the trend that variation followed over the five tension levels.

Freeman and Kendall (29) demonstrated that a reaction time task performed under induced muscular tension showed less variation than when performed under no tension. Similar results were obtained by Russel (60) when he found that the standard deviations obtained for three tension levels formed an inverted U curve. His subjects were required to toss balls at a target under three subjective states of tension - relaxed, natural and tense. The natural condition not only produced the optimum accuracy but also exhibited the least variation.

Variation of reaction time and movement time in the complex task, for the present study, also followed an inverted U curve relationship (Figure V). This indicated that under mild induced muscular tension (in this instance five and ten pounds) performance variation was reduced. At first it would seem that the above results contradict those that were obtained from the simple task (refer to Figure V). However consideration would have to be given to the hypothesis that, in terms of variability, the simple task was so easy that at the zero tension level subjects were already performing at a base level. Consequently tension served only to add extraneous factors to the task at hand and increased variability resulted. In comparison, mild tension conceivably could have directed more of the subject's attention towards the complex task which resulted in less variability. Excessive tension in the complex task, as in the simple task, only added factors that were extraneous to the performance of the task.

<u>Comparison Of Tasks In Reaction Time When Tension Levels Are Averaged Together</u>. In order to properly interpret the result that was obtained for the main effect of tasks (Table III) one should have been familiar with the basic split-plot design employed in the present study. The particular F attained for the above comparison implied a test of significance between the two tasks when the tension levels were averaged together for each task. In other words there was a "dampening" effect across the tension levels. Quite conceivably important differences between tasks could have been masked as a result of the averaging effect. Therefore it was imperative that any main effect, in a design of this type, be interpreted in light of the corresponding interaction effect.

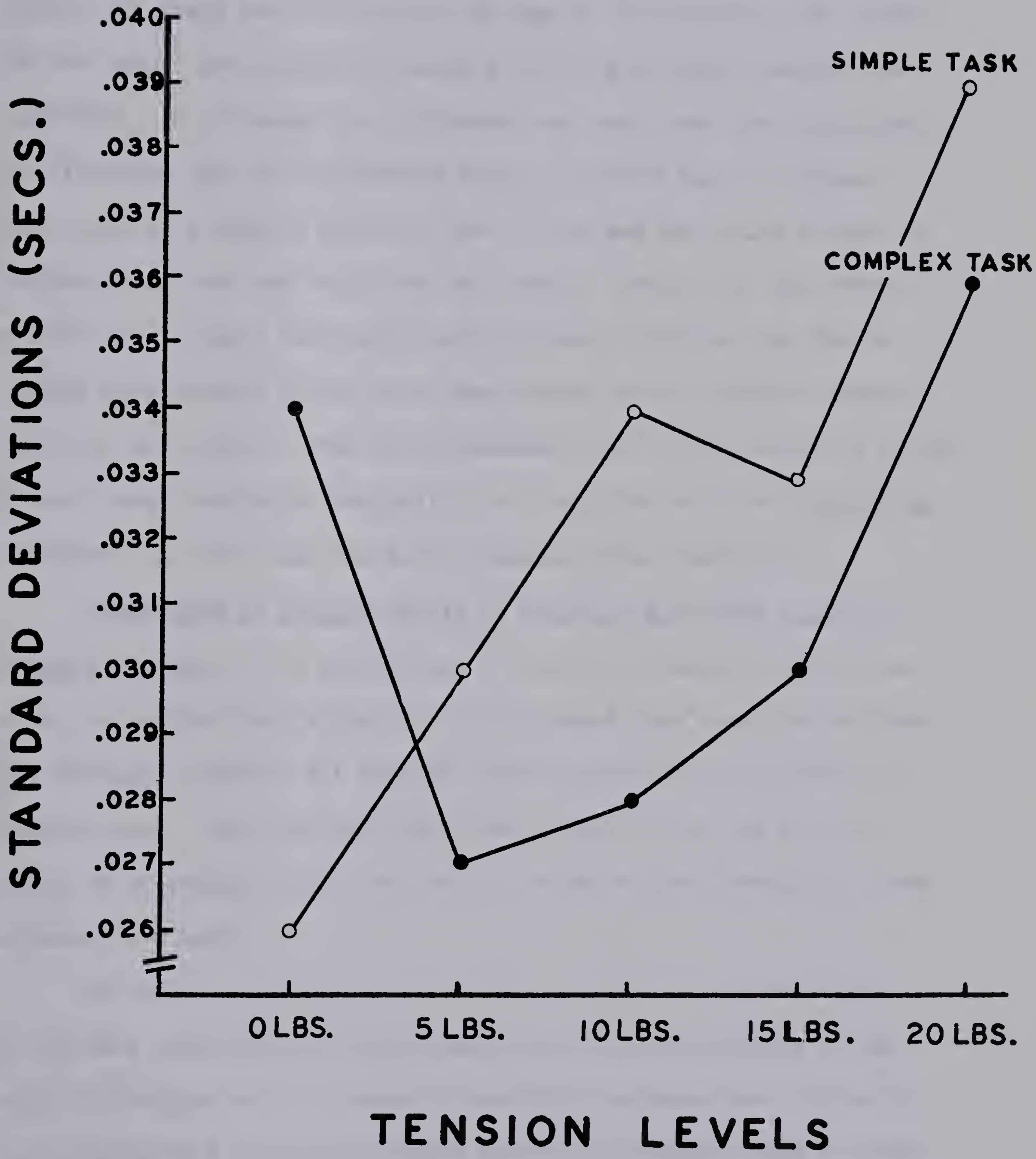

FIGURE V. PROFILE SHOWING THE VARIATION OF PERFORMANCE FOR THE SIMPLE AND COMPLEX TASKS.

Basically, then, judgement concerning the difference between tasks was reserved until the interaction effect had been examined. However, one interesting observation was made. When the sums of squares for tasks was calculated, the sum of the reaction time scores for the simple and complex tasks were 47.718 and 48.983 seconds, respectively. Even though the difference was small and non-significant, the direction that the difference took, indicated that the simple task required a shorter reaction time. Such was the prime purpose of the apparatus that was built for this study. Henry (34) had hypothesized that a simple task would have a faster reaction time than a complex task because of the more complicated neural impulses associated with the latter. That this phenomenon was in fact achieved in the present study enabled an analysis to be completed with the underlying assumption that one task was more elementary than the other.

<u>Comparison Of Tension Levels In Reaction Time When Tasks Are Averaged Together</u>. The significant F that was obtained for the main effect of tension levels (Table III) indicated that when the two tasks were averaged together all tension levels proved not to be equal in reaction time. Like the previous F test (tasks) this one also involved an averaging effect and hence in terms of past research no comparisons were made.

In effect, the significant F value signified that regardless of the task being performed reaction time was differentiated on the basis of tension levels. Duncan's New Multiple Range Test (Table IV) demonstrated that the significant F was due to the fact that reaction times under twenty pounds of tension were significantly slower from

all other reaction times.

Inspection of the means for each tension level revealed that at fifteen pounds, reaction time tended to be faster than at either five, ten or twenty pounds. Although in most cases the difference was very small and non-significant, this offered support to the activation hypothesis. Explained in detail by Duffy (16,17) and investigated through experimentation by several other authors (27,32,66,69), the activation hypothesis contends that muscular tension, by increasing the activation of a subject, facilitates performance until an optimal level is reached. When this point is surpassed, performance is impeded. Disregarding the reaction time for zero pounds of tension it was noted that fifteen pounds would have then served as an optimal tension level for reaction time and when combined with the data for five, ten and twenty pounds would have yielded an approximate inverted U curve. An hypothesis on the reasons for this phenomenon is offered in a later section.

<u>Interaction Of Tasks With Tension Levels</u>. From Table III the insignificant F value for the interaction effect indicated that the difference of the reaction times between tasks was essentially the same for all tension levels. In other words, the five tension levels had approximately the same effect on performance regardless of the task being performed. As mentioned earlier, however, the experimental design was not limited because of the insignificant F value and further comparisons were consequently carried out.

Past evidence (17,23) has indicated that performance not only depends upon the nature of the task, but in general, it has been sug-

gested that tasks of a complex nature may be handicapped by a high degree of activation while relatively simple tasks may be facilitated. In terms of the inverted U hypothesis a simple task should reach its optimal point at a higher tension level than would a complex task. As a result, given a range of particular tension levels that start at zero, the simple task would yield an inverted U curve that was skewed to the left with the complex task producing just the opposite effect.

The particular experimental design that was employed in this study enabled a trend analysis to be performed on the interaction (Table VI). More specifically, the F obtained for the quadratic analysis was a direct test of the difference between tasks in terms of the inverted U hypothesis mentioned above. In other words, the difference of the degree of curvature over the tension levels between tasks was tested. The obtained F was non-significant and resulted in failure to reject the null hypothesis. This result plus the fact the seventy-eight percent of the interaction sum of squares was accounted for by the two tests, led to the conclusion that a trend to describe the interaction could not be established. Hence past theory was not supported in this particular instance. However, further information as to the type of relationship that existed between tasks and tension levels was obtained from individual comparisons.

These individual comparisons (an F statistic applied to the difference between tasks at each tension level - Table IX) indicated that the difference between tasks at fifteen pounds approached significance while the difference at twenty pounds was significant. In both cases the complex task represented the slower times. These

results offered proof for the hypothesis that the complex task was hindered more by excessive tension than was the simple task.

Very similar to the results obtained here was the outcome of a study by Ryan (63). Using a stabilometer which could be varied in difficulty of performance Ryan used shock as his measure of activation. He had hypothesized that shock would hinder performance on the complex task while facilitating it on the simpler one. On examination of the results he found that the complex task actually showed a decrement in performance but that the simple task failed to be facilitated. The suggestion was given that possibly the simple task was too complex for facilitation to have occurred.

Freeman (27) has also given support to the above hypothesis. His results indicated that the optimal loading point of tension occurred earlier for mirror-drawing than for the simpler task of finger-oscillation. He concluded, the more complex the performance, the earlier will the tension increment show inhibitory effects.

Generalized tension, caused by the carrying of a pack board, also produced a differential effect when two tasks of different complexity were compared. Gregg (31) observed a decrement for a complex steadiness task but continued improvement for a tapping task when they were performed under tension.

In effect then, the results of the present study have supported past evidence but at the same time have failed to completely verify the activation hypothesis. Ideally, both tasks should have been facilitated, but at different tension levels, and both should have been hindered at higher tension levels. That only the complex task was

impeded while neither task was facilitated by tension leaves room for speculation. Suggestions as to why the results deviated from theory are given in a later section.

That neither task was facilitated by the presence of muscular tension both contradicted and supported past evidence. Studies that employed tasks such as a two handed matching test (1), a pursuit rotor (5), and a tracking task (59) found that muscular tension did not only fail to facilitate performance but also that in some instances, a decrement in performance occurred. Courts (9) however, discovered that muscular tension facilitated performance on the pursuit rotor. Investigators that have studied the effect of muscular tension on reaction time have also observed results similar to those of above. Kagan (37) came to the conclusion that pre-induced muscular tension increased reaction time. Teichner (72) was in agreement with Kagan when the former stated that simple reaction time was inversely related to the magnitude of muscular tension. Freeman and Kendall (29) were the only authors who have reported a facilitation effect due to the effects of muscular tension.

Additional information, arising from the data of the interaction effect, comes from two range tests performed on each task. Table VII indicates that for the simple task none of the means were significantly different from one another. On the other hand Table VIII shows that for the complex task the mean performance for twenty pounds was significantly slower than all other means. Two outcomes were apparent from these tests. First, the same conclusion that was made using the F statistic for individual comparisons was drawn here. That is, the

complex task is hindered by excessive tension. However these range tests also allowed a comparison among the tension levels for each task. Although these tests were intrinsically a part of the main interaction effect it was decided to calculate them for the purpose of investigating the reaction times of each task.

The simple task means, although all differences were non-significant, produced an interesting trend. Even though the data did not yield an inverted U curve, the mean at fifteen pounds was the smallest for the simple task. This indicated that an optimum point was reached at fifteen pounds. Further, the simple task was not impeded by tension at any one level.

On the other hand, the complex task's optimum tension level, although not significant, came at zero pounds with the mean at ten pounds being almost idential. Also, contrary to the simple task, performance at twenty pounds of tension was significantly slower than all other means.

Subjectively then, there was evidence that indicated that the optimal loading point for the simple task came at a higher tension level than for the complex task. Again this was support for the hypothesis that performance depended upon both activation and nature of the task (17,23,27,31,63).

Therefore, in summary, an investigation of the tensions by tasks interaction effects produced the following results: (1) The complex task was significantly impeded by excessive tension whereas no such phenomenon occurred for the simple task; (2) Neither task was significantly facilitated by the effects of tension. However, the data did

indicate that an optimal loading point occurred earlier for the complex task than it did for the simple task.

That the data for reaction time did not follow the expected theoretical framework was explained by several hypotheses. First, it was theorized that a significant facilitation effect was not obtained because both tasks were too complex and hence any induced tension would serve to hinder performance. Duffy offers support for this when she stated (17:187): "...relatively simple tasks, such as a conditioned response, may be facilitated." Since neither task was as simple as a conditioned response, facilitation, perhaps, should not be expected to occur. However, the data that was collected from this study suggest that an optimal point was reached in both tasks where reaction time was approximately equal to that which occurred at zero pounds of tension. Because such was the case, Duffy's statement must be interpreted with caution and no conclusions should be drawn until more definitive work is completed in this area. Furthermore, if Duffy's statement were true, the practical value of using induced muscular tension to facilitate performance would be questionable in the area of physical education since most activities involve complex coordination.

An alternate hypothesis to the one of above may be described with the help of Henry's neuro-motor drum theory (34). In effect this theory maintains that a more complex act requires a longer reaction latency because a larger neural program is required to carry the act to completion. If this were the case it might be expected that performance in the present study, at zero pounds of tension would be a simpler act than that at any of the induced tension levels. That is,

pressing the tension bar down to the horizontal was an act of skill in itself, and when added to the responsibility of reacting when the stimulus light was presented, a fairly complex act resulted. Therefore, it was suggested that zero pounds of tension should not have been taken as the control condition. Only the reaction times that required induced muscular tension should have been compared. Having followed this procedure, it became apparent that the present data would have indicated more of a facilitative effect than it had done. Even though differences still would probably not have been significant a stronger trend towards the hypothesized direction would have been obtained.

The latter of these two hypotheses offers the most promise. Probably not entirely correct, the hypothesis covered the most prominent problem of this study, i.e., the correct method of inducing muscular tension so as not to interfere with the task itself. No solutions were offered here, but it is entirely plausible that once this difficulty is overcome, research in the area of activation will become more fruitful.

Comparison Of Movement Times Among The Tension Levels Of The Complex Task. A complete dearth of empirical research in the area of speed of movement time and pre-induced muscular tension has led to the inclusion of this phenomenon in the present study. The three statistical tests that were run on the movement time data (analysis of variance, range test and trend analysis) all suggested that there was a linear relationship between tension level and speed of movement. That is, an increase in pre-induced muscular tension was associated with

increased movement time. There was no doubt that tension served to drastically slow down the ability to move. A possible explanation, on why the activation hypothesis did not apply in this instance, was phrased in terms of a specificity hypothesis. The prime purpose of this study was to study tension and reaction time. Hence the testing apparatus was structured in such a way that the muscles involved in reaction time were the ones in which tension was present. On examination of the complete task, it was noticed that some of those muscles which were required for the movement phase were actually antagonistic to those that were necessary for the reaction. Therefore a theory of specificity was presented. Not only is tension necessary for an act to be facilitated but also tension must be built up in those muscles required by that specific act.

The hypothesis that the movement time was more complex than reaction time, so that even a very small amount of tension would hinder its execution, was also given consideration.

Until further evidence is accumulated there is no certainty as to which hypothesis is correct.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to investigate the relationship between pre-induced muscular tension and reaction time of a simple and a complex task. A subsidiary problem included the study of movement time for the complex task. Ninety-two freshman university students were randomly selected as subjects. Each subject was then randomly assigned to either a simple reaction time task or to a more complex task that required both a reaction and a movement. Eight trials, at each of five randomly assigned pre-tension levels, were given to all subjects. The pre-tension levels were zero, five, ten, fifteen and twenty pounds.

The conclusions were as follows:

1. Pre-induced muscular tension did not serve to significantly facilitate reaction time on either of the two tasks.

2. Muscular tension significantly retarded reaction time in the complex task at twenty pounds of tension while not significantly impeding reaction time in the simple task. This conclusion seemed to have supported the activation hypothesis which stated a complex task would be hindered by tension at a lower level than would a simpler task.

3. The only difference between tasks, at each tension level, that reached statistical significance was the difference at twenty pounds of tension. This conclusion is in direct support of the hypothesis that stated that under excessive tension a faster reaction time would be associated with the task that required the simplest

execution.

4. Movement time displayed a linear relationship with increases in pre-induced muscular tension. A specificity hypothesis was offered as an explanation for this result that apparently contradicted the activation hypothesis.

<u>Recommendations</u>.

1. Before investigation can continue in this area a method of inducing muscular tension must be developed so that the subject can attend totally to the task at hand and not be distracted with the added responsibility of inducing tension. For the present study, the higher tension levels were relatively difficult to perform under and the decrement that was observed, especially at twenty pounds, could have resulted from the subject's attention being diverted from the task to the act of inducing tension. Support for this viewpoint comes from an inspection of the data of the present thesis. It appeared that reaction time was slightly facilitated at fifteen pounds for the simple task and at ten pounds for the complex task. Perhaps, if it had not been for the distracting influence of inducing tension, a significant facilitating effect would have occurred and the activation hypothesis would have been completely supported.

2. A method should be developed whereby a discrete type of task, such as the ones utilized here, can be studied with tension remaining induced throughout the entire task. In the present study only <u>pre</u>-induced muscular tension was used. Once the subjects reacted the movement phase was free of muscular tension. This could possibly be the reason why no facilitation of movement time occurred.

3. The effect of tension on a simple conditioned response, such as the patellar reflex, should be investigated. In this way there will be less uncontrolled variation and the specific effects of tension can be better delineated.

4. Muscle tension and its effect on learning should also be studied. This study only dealt with the short term effects of tension on performance. Perhaps tension will have a greater role to play in the learning of tasks or in their long term retention.

BIBLIOGRAPHY

BIBLIOGRAPY

1. Adams, J.A. "Effect of Experimentally Induced Muscular Tension on Psychomotor Performance," Journal of Experimental Psychology, 48 (1954), 127-130.

2. Adams, J.P. "Motor Skills," Annual Review of Psychology, 15, (1964), 181-197.

3. Bartoshuk, A.K. "Electromyographic Gradients as Indicants of Motivation," Canadian Journal of Psychology, 9 (1955), 215-230.

4. Bartoshuk, A.K. "Electromyographic Gradients in Goal Directed Activity," Canadian Journal of Psychology, 9 (1955), 21-28.

5. Bell, H.A. "Effects of Experimentally Induced Muscular Tension and Frequency of Motivational Instructions on Pursuit Rotor Performance," Perceptual and Motor Skills, 9 (1959), 111-115.

6. Broadhurst, P.L. "Emotionality and Yerkes-Dodson Law," Journal of Experimental Psychology, 54 (1957), 345-352.

7. Chang, H.T., Ruch, T.C., and Ward, A.A. "Topographical Representation of Muscles in the Motor Cortex of Monkeys," Journal of Neurophysiology, 10 (1947), 39-56.

8. Combs, A.W. and Taylor, C. "The Effect of the Perception of Mild Degrees of Threat on Performance," Journal of Abnormal Social Psychology, 47 (1952) 420-424.

9. Courts, F.A. "The Influence of Practice on the Dynamogenic Effect of Muscular Tension," Journal of Experimental Psychology, 30 (1942), 504-511.

10. ______ . "Relations Between Muscular Tension and Performance," Psychological Bulletin, 39 (1942), 347-367.

11. Duffy, E. "The Relation Between Muscular Tension and Quality of Performance," American Journal of Psychology, 44 (1932), 535-546.

12. ______ . "The Conceptual Categories of Psychology: A Suggestion for Revision," Psychological Review, 48 (1948), 177-203.

13. ______ . "Level of Muscular Tension as an Aspect of Personality," Journal of General Psychology, 35 (1946), 161-171.

14. ______ . "A Systematic Framework for the Description of Personality," Journal of Abnormal and Social Psychology, 44 (1949) 175-190.

15. ______ . "The Concept of Energy Mobilization," Psychological Review, 58 (1951), 30-40.

16. ______ . "The Psychological Significance of the Concept of Arousal or Activation," Psychological Review, 64 (1957), 265-275.

17. ______ . Activation and Behavior. New York: Wiley, 1962.

18. Eason, R.G. "The Surface Electromyogram Gauges Subjective Effort," Perceptual and Motor Skills, 9 (1959), 359-361.

19. ______ . "Relationship Between Effort, Tension Level, Skill, and Performance Efficiency in a Perceptual Motor Task," Perceptual Motor Skills, 16 (1963), 297-317.

20. ______ and Branks, J. "Effect of Level of Activation on the Quality and Efficiency of Performance of Verbal and Motor Tasks," Perceptual and Motor Skills, 16 (1963), 523-543.

21. ______ and White, C.T. "Relationship Between Muscular Tension and Performance During Rotory Pursuit," Perceptual Motor Skills, 10 (1960), 199-210.

22. ______ . "Muscular Tension, Effort, and Tracking Difficulty: Studies of Parameters Which Affect Tension Level and Performance Efficiency," Perceptual Motor Skills, 12 (1961), 331-372.

23. Easterbrook, J.A. "The Effect of Emotion on Cue Utilization and the Organization of Behavior," Psychological Review, 66 (1959), 183-201.

24. Edwards, A.L. Experimental Design in Psychological Research. New York: Holt, Rinehart and Winston, 1963.

25. Eysenck, J.J. Experiments in Motivation. New York: The Macmillan Company, 1964.

26. Freeman, G.L. "The Facilitative and Inhibitory Effects of Muscular Tension Upon Performance," American Journal of Psychology, 45 (1933), 17-52.

27. ______ . "The Optimal Muscular Tensions for Various Performances," American Journal of Psychology, 51 (1938), 146-150.

28. ______ . "The Relationship Between Performance Level and Bodily Activity Level," Journal of Experimental Psychology, 26 (1940), 602-608.

29. _______ and Kendall, W.E. "The Effect Upon Reaction Time of Muscular Tension Induced at Various Preparatory Conditions," Journal of Experimental Psychology, 27 (1940), 136-148.

30. _______ and Simpson, R.M. "The Effect of Muscular Tension Upon Palmar Skin Resistance," Journal of General Psychology, 18 (1938), 319-326.

31. Gregg, L.W. "Changes in Distribution of Muscular Tension During Psychomotor Performance," Journal of Experimental Psychology, 56 (1958), 70-77.

32. Hebb, D.O. "Drives and the Conceptual Nervous System," Psychological Review, 62 (1955), 243-253.

33. Henderson, R.L. "Remote Action Potentials at the Moment of Response in a Simple Reaction-Time Situation," Journal of Experimental Psychology, 44 (1952), 238-241.

34. Henry, F.M. "Increased Response Latency for Complicated Movements and a "Memory Drum" Theory of Neuromotor Reaction," Research Quarterly, 31 (1960), 448-458.

35. Howell, M.L. "Influence of Emotional Tension on Speed of Reaction and Movement," Research Quarterly, 24 (1953), 22-32.

36. Jacobson, E. "Muscular Tension and the Estimation of Effort," American Journal of Psychology, 64 (1951), 112-116.

37. Kagan, H. "Muscular Tension, Task Resistance and Speed of Response," The Psychological Record, 14 (1964), 417-425.

38. Kausler, D.H. and Trapp, E.P. "Motivation and Cue Utilization in Intentional and Incidental Learning," Psychological Review, 67 (1960), 373-379.

39. Kennedy, J.L. and Travis, R.C. "Prediction and Control of Alertness, II Continuous Tracking," Journal of Comparative Physiological Psychology, 41 (1948), 203-210.

40. Kerr, B.A. "The Effect of Strength Training Upon Speed of Movement and Reaction Time in a Knee Extension Movement," Unpublished Thesis from the University of Alberta, 1964.

41. Klein, S.J. "Relation of Muscle Action Potentials Variously Induced to Breakdown of Work in Task-Oriented Subjects," Perceptual Motor Skills, 12 (1961), 131-141.

42. Kling, J.W. and Schlosberg, H. "The Relationship Between Tension and Efficiency," Perceptual Motor Skills, 9 (1959), 395-397.

43. ______ . "Relation of Skin Conductance and Rotory Pursuit During Extended Practice," Perceptual Motor Skills, 12 (1961), 270.

44. Kling, J.W., Williams, J.P. and Schlosberg, H. "Patterns of Skin Conductance," Perceptual Motor Skills, 9 (1959), 303-312.

45. Kuethe, J.L. and Eriksen, C.W. "Personality, Anxiety, and Muscle Tension as Determinants of Response Stereotypy," Journal of Abnormal and Social Psychology, 54 (1957), 400-404.

46. Lansing, R.W., Schwartz, E. and Lindsley, D.B. "Reaction Time and EEG Activation Under Alerted and Non-Alerted Conditions," Journal of Experimental Psychology, 58 (1959), 1-7.

47. Lazarus, R.S. and Erikson, C.W. "Effects of Failure Stress Upon Skilled Performance," Journal of Experimental Psychology, 43 (1952), 100-105.

48. Leuba, C. "Toward Some Integration of Learning Theories: The Concept of Optimal Stimulation," Psychological Report, 1 (1955), 27-33.

49. Lindsley, D.B. "Psychological Phenomena and the Electroencephalogram," Journal of Neurophysiology, 4 (1952), 443-456.

50. ______ . "Physiological Psychology" Annual Review of Psychology, 7 (1956), 323-348.

51. ______. "Psychoplysiology and Motivation," Nebraska Symposium on Motivation, (1957), 44-103.

52. Malmo, R.B. "Measurement of Drive: An Unsolved Problem in Psychology," Nebraska Symposium on Motivation, (1958), 224-265.

53. ______ . "Activation: A Neuropsychlolgical Dimension," Psychological Review, 66 (1959), 367-386.

54. ______ and Davis, J.F. "Physiological Gradients as Indicants of Arousal in Mirror Tracing," Canadian Journal of Psychology, 10 (1956), 231-238.

55. Meyer, D.R. "On the Interaction of Simultaneous Responses," Psychological Bulletin, 50 (1953), 204-220.

56. Moeller, G. and Chattin, C.P. "The Palmer Perspiration Index and Pursuit Tracking," Perceptual Motor Skills, 15 (1962), 463-473.

57. Noble, C.E. "An Attempt to Manipulate Incentive Motivation in a Continuous Task," Perceptual Motor Skills, 5 (1955), 65-69.

58. Patrick, J.R. "Studies in Rational Behavior and Emotional Excitement: II The Effect of Emotional Excitement on Rational Behavior in Human Subjects," Journal of Comparative Psychology, 18 (1934), 153-195.

59. Pinneo, L.R. "The Effects of Induced Muscle Tension During Tracking on Level of Activation and on Performance," Journal of Experimental Psychology, 62 (1961), 523-531.

60. Russell, J.T. "Relative Efficiency of Relaxation and Tension in Performing an Act of Skill," Journal of General Psychology, 6 (1932), 330-343.

61. Ryan, E.D. "The Effect of Differential Motive-Incentive Conditions on Physical Performance," Research Quarterly, 32 (1961) 83-87.

62. ______ . "Relationship Between Motor Performance and Arousal," Research Quarterly, 33 (1962), 279-287.

63. ______ . "Effects of Stress on Motor Performance and Learning," Research Quarterly, 33 (1962), 111-119.

64. ______ . "The Relationship of Galvanic Skin Conductance to Ring-Peg Performance," Research Quarterly, 34 (1963), 526-528.

65. Schaffer, H.R. "Behavior Under Stress: A Neurophysiological Hypothesis," Psychological Review, 61 (1954), 323-333.

66. Schlosberg, H. "Three Dimensions of Emotion," Psychological Review, 61 (1954), 81-88.

67. ______ and Stanley, W.C. "A Simple Test of the Normality of Twenty-four Distributions of Electrical Skin Conductance," Science, 117 (1953), 35-37.

68. Sharpless, S. and Jasper, H. "Habituation of the Arousal Reaction," Brain, 79 (1956), 655-680.

69. Stennett, R.G. "The Relationship of Performance Level to Level of Arousal," Journal of Experimental Psychology, 54 (1957), 54-61.

70. Surwillo, W.W. "Psychological Factors in Muscle Action Potentials: EMG Gradients," Journal of Experimental Psychology, 52 (1956), 263-272.

71. Tecce, J.J. and Tarnell, M. "Focal and Incidental Movement Time as A Function of Shock Arousal in Humans," Journal of Psychology, 59 (1965), 155-158.

72. Teichner, W.H. "Effects of Foreperiod, Induced Muscular Tension, and Stimulus Regularity on Simple Reaction Time," Journal of Experimental Psychology, 53 (1957), 277-284.

73. Travis, R.C. and Kennedy, J.L. "Prediction and Automatic Control of Alertness; I Control of Lookout Alertness," Journal of Comparative Physiological Psychology, 40 (1947), 457-461.

74. _______ . "Prediction and Control of Alertness: III Calibration of the Alertness Indicator and Further Results," Journal of Comparative Physiological Psychology, 42 (1949), 45-57.

75. Wilcott, R.C. and Beenken, H.G. "Relation of Integrated Surface Electromyography and Muscle Tension," Perceptual Motor Skills, 7 (1957), 295-298.

76. Winer, B.J. Statictical Principles in Experimental Design. McGraw-Hill Book Company, Toronto, 1962.

77. Woodworth, R.S. and Schlosberg, H. Experimental Psychology. Holt, Rinehart and Winston Inc., New York, 1963.

APPENDIX

APPENDIX A

RAW SCORES

MEAN REACTION TIMES FOR THE SIMPLE TASK
(SECONDS)

Subject	0 Lbs.	5 Lbs.	10 Lbs.	15 Lbs.	20 Lbs.
1	.187	.199	.232	.229	.173
2	.208	.215	.228	.205	.228
3	.202	.177	.193	.171	.218
4	.219	.206	.213	.241	.258
5	.194	.222	.233	.215	.232
6	.199	.162	.185	.165	.169
7	.192	.205	.194	.237	.218
8	.202	.185	.188	.185	.177
9	.178	.180	.164	.145	.171
10	.193	.213	.204	.200	.225
11	.240	.232	.230	.256	.340
12	.175	.180	.185	.159	.212
13	.318	.245	.294	.287	.291
14	.187	.180	.175	.183	.195
15	.199	.245	.218	.222	.199
16	.201	.181	.157	.155	.159
17	.210	.216	.197	.201	.175
18	.181	.195	.185	.177	.160
19	.216	.200	.218	.188	.194
20	.190	.186	.180	.196	.175
21	.165	.185	.181	.165	.195
22	.184	.169	.170	.176	.190
23	.210	.192	.190	.217	.241
24	.231	.212	.226	.238	.242
25	.209	.213	.193	.182	.202
26	.174	.177	.200	.167	.144
27	.222	.247	.225	.213	.256
28	.216	.220	.223	.221	.221
29	.220	.223	.233	.216	.240
30	.219	.223	.255	.259	.235
31	.203	.243	.218	.229	.241
32	.217	.207	.220	.175	.190
33	.214	.184	.187	.182	.170
34	.195	.222	.192	.203	.235
35	.191	.178	.168	.167	.172
36	.208	.213	.209	.207	.226
37	.230	.218	.235	.205	.211
38	.201	.196	.217	.209	.225
39	.204	.213	.206	.236	.181
40	.234	.264	.265	.244	.263
41	.223	.187	.199	.204	.227
42	.240	.327	.325	.277	.276
43	.189	.181	.183	.171	.227
44	.194	.216	.285	.242	.188
45	.165	.177	.193	.222	.185
46	.171	.193	.178	.175	.174

MEAN REACTION TIMES FOR THE COMPLEX TASK
(SECONDS)

Subject	0 Lbs.	5 Lbs.	10 Lbs.	15 Lbs.	20 Lbs.
1	.180	.190	.192	.195	.191
2	.257	.255	.242	.320	.287
3	.182	.171	.189	.160	.161
4	.240	.237	.215	.234	.171
5	.192	.219	.245	.202	.254
6	.196	.256	.211	.214	.228
7	.223	.199	.196	.225	.224
8	.173	.194	.206	.217	.208
9	.216	.234	.217	.206	.215
10	.191	.202	.199	.210	.224
11	.168	.179	.180	.200	.262
12	.228	.217	.194	.211	.241
13	.189	.183	.197	.191	.227
14	.171	.164	.157	.161	.181
15	.280	.265	.272	.267	.270
16	.161	.181	.182	.181	.154
17	.231	.215	.205	.210	.237
18	.178	.185	.199	.210	.228
19	.230	.253	.280	.274	.329
20	.219	.246	.215	.206	.183
21	.182	.173	.170	.172	.172
22	.211	.224	,245	.195	.235
23	.256	.222	.223	.226	.218
24	.218	.251	.242	.248	.219
25	.216	.205	.207	.220	.242
26	.172	.208	.190	.250	.259
27	.177	.183	.214	.188	.264
28	.181	.176	.163	.210	.192
29	.209	.222	.219	.211	.266
30	.255	.230	.254	.227	.215
31	.226	.223	.213	.205	.239
32	.219	.235	.205	.210	.229
33	.179	.198	.207	.196	.246
34	.230	.230	.236	.237	.219
35	.274	.212	.193	.208	.222
36	.235	.213	.195	.178	.175
37	.167	.180	.192	.195	.196
38	.170	.231	.246	.261	.251
39	.240	.220	.211	.200	.211
40	.228	.184	.198	.207	.217
41	.199	.213	.222	.232	.210
42	.280	.256	.251	.234	.262
43	.238	.178	.179	.186	.195
44	.179	.171	.157	.161	.149
45	.136	.217	.195	.209	.253
46	.236	.213	.235	.201	.205

MEAN MOVEMENT TIMES FOR THE COMPLEX TASK
(SECONDS)

Subjects	0 Lbs.	5 Lbs.	10 Lbs.	15 Lbs.	20 Lbs.
1	.399	.414	.488	.535	.446
2	.696	.854	.694	.905	.759
3	.291	.455	.375	.365	.436
4	.495	.534	.516	.531	.455
5	.533	.633	.577	.499	.651
6	.522	.743	.610	.615	.539
7	.457	.422	.493	.495	.489
8	.380	.394	.406	.402	.450
9	.507	.510	.567	.515	.574
10	.540	.597	.552	.580	.542
11	.476	.622	.539	.509	.662
12	.576	.579	.588	.584	.719
13	.555	.509	.562	.584	.644
14	.470	.401	.497	.392	.549
15	.519	.531	.635	.580	.610
16	.373	.429	.463	.494	.395
17	.680	.440	.630	.509	.541
18	.495	.558	.603	.586	.664
19	.757	.671	.816	.955	.949
20	.509	.483	.525	.500	.458
21	.427	.478	.484	.412	.483
22	.437	.467	.516	.432	.505
23	.548	.511	.528	.757	.609
24	.386	.511	.509	.492	.455
25	.482	.511	.472	.544	.547
26	.500	.488	.491	.593	.547
27	.565	.538	.667	.653	.770
28	.398	.451	.456	.491	.524
29	.583	.696	.538	.525	.673
30	.438	.468	.516	.569	.544
31	.508	.637	.485	.554	.552
32	.573	.573	.505	.514	.609
33	.480	.603	.570	.677	.715
34	.553	.681	.766	.641	.655
35	.447	.454	.494	.533	.552
36	.469	.537	.412	.491	.445
37	.606	.564	.658	.702	.598
38	.610	.564	.562	.634	.673
39	.456	.516	.538	.572	.595
40	.521	.584	.588	.655	.591
41	.408	.472	.507	.446	.548
42	.509	.513	.564	.553	.612
43	.646	.474	.556	.511	.537
44	.465	.478	.455	.463	.509
45	.686	.569	.571	.705	.626
46	.792	.717	.711	.751	.788